



EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT - SECTION 313: Guidance for Reporting Toxic Chemicals within the Dioxin and Dioxin-like Compounds Category

Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) requires certain facilities manufacturing, processing, or otherwise using listed toxic chemicals to report the annual quantity of such chemicals entering each environmental medium. Such facilities must also report pollution prevention and recycling data for such chemicals, pursuant to section 6607 of the Pollution Prevention Act, 42 U.S.C. 13106. When enacted, EPCRA section 313 established an initial list of toxic chemicals that was comprised of more than 300 chemicals and 20 chemical categories. EPCRA section 313(d) authorizes EPA to add chemicals to or delete chemicals from the list, and sets forth criteria for these actions.

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Section 1.0. INTRODUCTION

Section 1.1. Background

On October 29, 1999, the Environmental Protection Agency (EPA) promulgated a final rule (64 FR 58666) adding a category of dioxin and dioxin-like compounds to the list of toxic chemicals subject to the reporting requirements under section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). The reporting threshold for the category was also established as 0.1 grams manufactured, processed, or otherwise used. The category listing is:

Dioxin and dioxin-like compounds (Manufacturing; and the processing or otherwise use of dioxin and dioxin-like compounds if the dioxin and dioxin-like compounds are present as contaminants in a chemical and if they were created during the manufacturing of that chemical)

The purpose of this guidance document is to assist facilities in complying with the reporting requirements of EPCRA section 313 for the dioxin and dioxin-like compounds category. EPCRA section 313 covered facilities that exceed the reporting threshold for the dioxin and dioxin-like compounds category are subject to the EPCRA section 313 annual reporting requirements beginning with reporting year 2000, with the first reports due by July 1, 2001.

This document explains the EPCRA section 313 reporting requirements, and provides guidance on how to estimate annual releases and other waste management quantities of dioxin and dioxin-like compounds to the environment from certain industries and industrial activities. Because each facility is unique, the recommendations presented may have to be adjusted to the specific nature of operations at your facility or industrial activity.

A primary goal of EPCRA is to increase the public's knowledge of, and access to, information on the presence and release and other waste management activities of EPCRA section 313 toxic chemicals in their communities. Under EPCRA section 313, certain facilities (see Section 1.2, below) exceeding certain thresholds (see Section 1.3) are required to submit reports (commonly referred to as Form Rs or Form A certification statements) annually. Reports must be submitted to EPA and State or Tribal governments, on or before July 1, for activities in the previous calendar year. The owner/operator of the facility on July 1 of the reporting deadline is primarily responsible for the report, even if the owner/operator did not own the facility during the reporting year. EPCRA also mandates that EPA establish and maintain a publicly available database consisting of the information reported under Section 313. This database, known as the Toxic Release Inventory (TRI), can be accessed through the following sources:

- EPA's Internet site, www.epa.gov/tri;
- Envirofacts Warehouse Internet site; www.epa.gov/enviro/html/tris/tris_overview.html;

- CD-ROM from the Government Printing Office (GPO);
- Microfiche in public libraries;
- Magnetic tape and diskettes from the National Technical Information Service; and
- EPA's annual TRI data release materials (summary information).

The objectives of this guidance document are to:

- Clarify EPCRA section 313 reporting requirements for the dioxin and dioxin-like compounds category;
- Promote consistency in the method of estimating annual releases and other waste management quantities of dioxin and dioxin-like compounds for particular industries and industrial classes;
- Reduce the level of effort expended by those facilities that prepare an EPCRA section 313 report for the dioxin and dioxin-like compounds category.

Section 1.2. Who Must Report?

A plant, factory, or other facility is subject to the provisions of EPCRA section 313, if it meets all three of the following criteria:

- C It is included in the primary Standard Industrial Classification (SIC) codes 20 through 39 or is in one of the following industries: Metal Mining, SIC code 10 (except SIC codes 1011, 1081, and 1094); Coal Mining, SIC code 12 (except SIC code 1241); Electric Utilities, SIC codes 4911, 4931, or 4939 (each limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce); Commercial Hazardous Waste Treatment, SIC code 4953 (limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. section 6921 *et seq.*); Chemicals and Allied Products-Wholesale, SIC code 5169; Petroleum Bulk Terminals and Plants, SIC code 5171; and, Solvent Recovery Services, SIC code 7389 (limited to facilities primarily engaged in solvent recovery services on a contract or fee basis); and
- C It has 10 or more full-time employees (or the equivalent of 20,000 hours per year); and
- C It manufactures (includes imports), processes or otherwise uses any of the toxic chemicals listed on the EPCRA section 313 list in amounts greater than the threshold quantities specified below.

In addition, pursuant to Executive Order 12856 entitled "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," federal facilities are required to comply with the reporting requirements of EPCRA section 313 beginning with calendar year 1994. This

requirement is mandated regardless of the facility's SIC code.

Section 1.3. What are the Reporting Thresholds?

Thresholds are specified amounts of toxic chemicals manufactured, processed, or otherwise used during the calendar year that trigger reporting requirements. The EPCRA section 313 dioxin and dioxin-like compounds category consists of seventeen specific compounds (see Section 1.4, Table 1-2) that are reported as a single chemical category. EPCRA section 313 requires threshold determinations for chemical categories to be based on the total mass of all the chemicals in that category. Reporting is required for the dioxin and dioxin-like compounds category:

- If a facility *manufactures* 0.1 grams of dioxin and dioxin-like compounds over the calendar year.
- If a facility *processes* 0.1 grams of dioxin and dioxin-like compounds over the calendar year.
- If a facility *otherwise uses* 0.1 grams of dioxin and dioxin-like compounds over the calendar year.

The terms manufacture, process, and otherwise use are defined at 40 CFR §372.3 as:

Manufacture means to produce, prepare, import, or compound a toxic chemical. Manufacture also applies to a toxic chemical that is produced coincidentally during the manufacture, processing, use, or disposal of another chemical or mixture of chemicals, including a toxic chemical that is separated from that other chemical or mixture of chemicals as a byproduct, and a toxic chemical that remains in that other chemical or mixture of chemicals as an impurity.

Otherwise use means any use of a toxic chemical, including a toxic chemical contained in a mixture or other trade name product or waste, that is not covered by the terms “manufacture” or “process.” Otherwise use of a toxic chemical does not include disposal, stabilization (without subsequent distribution in commerce), or treatment for destruction unless:

(1) The toxic chemical that was disposed, stabilized, or treated for destruction was received from offsite for the purposes of further waste management; or

(2) The toxic chemical that was disposed, stabilized, or treated for destruction was manufactured as a result of waste management activities on materials received from off-site for the purposes of further waste management activities. Relabeling or redistributing of the toxic chemical where no repackaging of the toxic chemical occurs does not constitute otherwise use or processing of the toxic chemical.

Process means the preparation of a toxic chemical, after its manufacture, for distribution in commerce: (1) In the same form or physical state as, or in a different form or physical state from, that in which it was received by the person so preparing such substance, or (2) As part of an article containing the toxic chemical. Process also applies to the processing of a toxic chemical contained in a mixture or trade name product.

The qualifier for the dioxin and dioxin-like compounds category places some limitations on what is covered by the category and thus certain processing or otherwise use activities that may involve dioxin and dioxin-like compounds are not reportable. See Section 1.5 for a detailed discussion of the qualifier and its impacts on reporting.

The quantities of dioxin and dioxin-like compounds included in threshold determinations are not limited to the amounts of these compounds released to the environment, they include all amounts of dioxin and dioxin-like compounds manufactured, processed, or otherwise at the facility. For example, some emission factors may include values for both before and after scrubbers, and while the after scrubber values would apply to release estimates, the before scrubber values would apply towards threshold calculations since this represents amounts that have been manufactured. Amounts estimated to be removed by scrubbers should also be reported according to how they are handled (e.g., released to land on-site, transferred off-site for disposal or destruction, etc.). If the only information that a facility has concerning the manufacturing, processing, or otherwise use of dioxin and dioxin-like compounds at the facility comes from emission factors then those quantities can be used to determine threshold quantities.

Section 1.4. What are Dioxin and Dioxin-like Compounds and Which Chemicals are Included in the EPCRA Section 313 Dioxin and Dioxin-like Compounds Category?

Polychlorinated dibenzo-para(p)-dioxins (CDDs) and polychlorinated dibenzofurans (CDFs) constitute a group of persistent, bioaccumulative, toxic (PBT) chemicals that are termed 'dioxin-like.' The term, 'dioxin-like' refers to the fact that these compounds have similar chemical structure, similar physical-chemical properties, and invoke a common battery of toxic responses. An important aspect to this definition is that the CDDs and CDFs must have chlorine substitution of hydrogen atoms at the 2, 3, 7, and 8 positions on the benzene rings.

A molecule of dibenzo-p-dioxin (DD) and dibenzofuran (DF) is a triple-ring structure consisting of two benzene rings interconnected by a third oxygenated ring (i.e., a ring containing an oxygen atom). In DD, the middle oxygenated ring contains two oxygen atoms that connect the benzene rings while in DF, the oxygenated ring contains one oxygen atom that joins the benzene rings. The molecular structure of DD and DF is depicted in Figure 1. As can be discerned in Figure 1, there is the possibility of substituting hydrogen atoms with chlorine atoms (or other halogens) at eight substituent positions along the DD and DF molecules (i.e., positions 1, 2, 3, 4, 6, 7, 8, or 9). This pattern of substitution creates the possibility of 75 chlorodibenzo-p-dioxin and

135 chlorodibenzofuran compounds. These individual compounds are technically referred to as congeners. Homologue groups are groups of congeners that have the same number of chlorine atoms attached to the molecule, but substituted in different positions as indicated by Cl_x and Cl_y in Figure 1. The prefix mono, di, tri, tetra, penta, hexa, hepta, and octa designates the total number of chlorines in the nomenclature of homologue groupings (i.e., molecules with either 1, 2, 3, 4, 5, 6, 7, or 8 chlorine atoms attached to the carbons). Isomerism is another important chemical descriptor, and refers to compounds with the same molecular formula (e.g., the same number of carbon, hydrogen, and chlorine atoms) but that differ by the location of the chlorine atoms on the benzene rings. Table 1-1 displays the total number of positional CDD and CDF isomers that are possible within each homologue group. The compounds with chlorine substitution in the 2, 3, 7, 8-positions on the molecule are the most toxic and bioaccumulate in mammalian systems, including humans.

Figure 1. Chemical Structure of Dioxin-Like Compounds

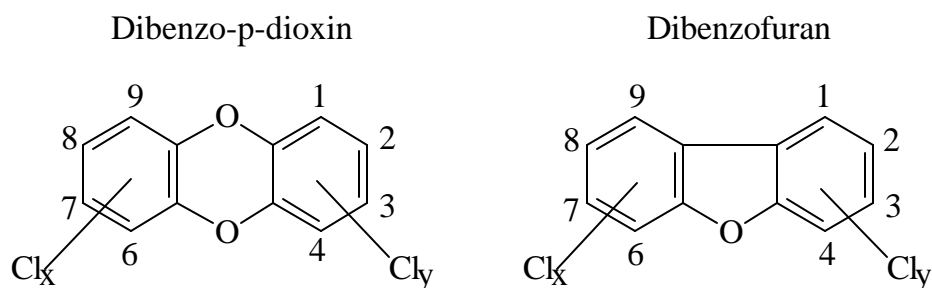


Table 1-1. Homologues and Positional Isomers of CDDs, CDFs

<i>Homologue (prefix)</i>	<i>Chlorine Atoms</i>	<i>Isomers of CDDs</i>	<i>Isomers of CDFs</i>
Mono	1	2	4
Di	2	10	16
Tri	3	14	28
Tetra (T)	4	22	38
Penta (Pe)	5	14	28
Hexa (Hx)	6	10	16
Hepta (Hp)	7	2	4
Octa (O)	8	1	1
Total possible congeners		75	135

The EPCRA section 313 dioxin and dioxin-like compounds category consists of seventeen specific CDD and CDF compounds, each having chlorine substitution at the 2, 3, 7, and 8 positions. Table 1-2 includes all of the members of the EPCRA section 313 dioxin and dioxin-like compounds category. These are the only CDD and CDF compounds that are reportable under the EPCRA section 313 dioxin and dioxin-like compounds category. The term “dioxin,” as in “dioxin

and dioxin-like compounds” refers to the most widely studied of these compounds, 2,3,7,8-tetrachlorodibenzo-p-dioxin (CAS No. 1746-01-6). Throughout this document the phrase “dioxin and dioxin-like compounds” refers to the seventeen chemicals listed in Table 1-2.

Table 1-2. Members of the EPCRA Section 313 Dioxin and Dioxin-like Compounds Category

CAS No.	Chemical Name	Abbreviated Name
CDDs		
1746-01-6	2,3,7,8-tetrachlorodibenzo-p-dioxin	2,3,7,8-TCDD
40321-76-4	1,2,3,7,8-pentachlorodibenzo-p-dioxin	1,2,3,7,8-PeCDD
39227-28-6	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	1,2,3,4,7,8-HxCDD
57653-85-7	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	1,2,3,6,7,8-HxCDD
19408-74-3	1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	1,2,3,7,8,9-HxCDD
35822-46-9	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	1,2,3,4,6,7,8-HpCDD
3268-87-9	1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	1,2,3,4,6,7,8,9-OCDD
CDFs		
51207-31-9	2,3,7,8-tetrachlorodibenzofuran	2,3,7,8-TCDF
57117-41-6	1,2,3,7,8-pentachlorodibenzofuran	1,2,3,7,8-PeCDF
57117-31-4	2,3,4,7,8-pentachlorodibenzofuran	2,3,4,7,8-PeCDF
70648-26-9	1,2,3,4,7,8-hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF
57117-44-9	1,2,3,6,7,8-hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF
72918-21-9	1,2,3,7,8,9-hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF
60851-34-5	2,3,4,6,7,8-hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF
67562-39-4	1,2,3,4,6,7,8-heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF
55673-89-7	1,2,3,4,7,8,9-heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF
39001-02-0	1,2,3,4,6,7,8,9-octachlorodibenzofuran	1,2,3,4,6,7,8,9-OCDF

EPA regulations require threshold determinations, and release and other waste management quantities for chemical categories to be based on the total mass of all the chemicals in the category. Thus for the dioxin and dioxin-like compounds category only one Form R is prepared and it contains the total amounts of all members of the category. While individual reporting of each

member of the dioxin and dioxin-like compounds category listed in Table 1-2 is not required, the Form R does contain a section for reporting the distribution of dioxin and each dioxin-like compound for the total quantity that the facility is reporting. This distribution must be reported if the information is available from the data used to calculate thresholds, releases, and other waste management quantities. The distribution must either be the distribution that best represents the distribution of the total quantity of dioxin and dioxin-like compounds released to all media from the facility or the facility's one best media specific distribution. When using the default emission factors listed in Section 4.0 the distribution associated with the emission factor should be reported unless the facility has a better distribution available.

Section 1.5. What Activities are Covered by the Qualifier for the Dioxin and Dioxin-like Compounds Category?

The dioxin and dioxin-like compounds category has the following activity qualifier that describes what must be reported under the category:

“Manufacturing; and the processing or otherwise use of dioxin and dioxin-like compounds if the dioxin and dioxin-like compounds are present as contaminants in a chemical and if they were created during the manufacturing of that chemical.”

This qualifier means that if a facility manufactures dioxin and dioxin-like compounds then those quantities must be applied towards the 0.1 gram manufacturing threshold and included in release and other waste management calculations. The qualifier also covers the processing or otherwise use of dioxin and dioxin-like compounds but only if the dioxin and dioxin-like compounds are present as contaminants in a chemical and if they were created during the manufacturing of that chemical. This means that if a facility processes or otherwise uses a chemical or mixture that contains dioxin and dioxin-like compounds that were created during the manufacturing of that chemical or mixture, then the dioxin and dioxin-like compounds must be included in threshold determinations and release and other waste management calculations.

Examples of the impacts of the dioxin and dioxin-like compounds category qualifier on what is reportable:

Example 1: The qualifier for the dioxin and dioxin-like compounds category states that if a facility is processing or otherwise using a chemical A that contains dioxin and dioxin-like compounds such activities are reportable but only if the dioxin and dioxin-like compounds were created during the manufacturing of chemical A. This means that any facility that processes or otherwise uses chemical A would need to consider the dioxin and dioxin-like compounds contained in chemical A.

However, if a facility uses chemical A to make another chemical B and the dioxin and dioxin-like compounds in chemical A are incorporated into chemical B and chemical B

is sold, then the other facilities that process or otherwise use chemical B would not have to consider the dioxin and dioxin-like compounds in chemical B because they were not created during the manufacturing of chemical B.

Example 2: Waste management facilities are otherwise using dioxin and dioxin-like compounds when waste that contains dioxin or dioxin-like compounds is received from off-site for the purposes of on-site waste management (i.e., disposal, stabilization or treatment). Such facilities need to consider if:

the dioxin and dioxin-like compounds are present as contaminants that were created during the manufacturing of chemicals in the waste received from off-site.

If so, then the qualifier for the dioxin and dioxin-like compounds category has been met and the dioxin and dioxin-like compounds should be considered toward threshold determinations and release and other waste management calculations. The determination regarding whether the qualifier for the dioxin and dioxin-like compounds category has been met may be more difficult for some waste streams (e.g., contaminated soil and debris), than for other waste streams (e.g., closely monitored manufacturing process waste streams). Nevertheless, facilities should use their best readily available data to determine if the dioxin and dioxin-like compounds are present as contaminants that were created during the manufacturing of the chemicals that are being otherwise used.

There are several chemicals that EPA has identified as having the potential to contain dioxin and dioxin-like compounds manufactured as by-products during the manufacturing process for those chemicals. These chemicals include, but are not limited to:

<u>CAS No.</u>	<u>Chemical Name</u>	<u>Typical Uses</u>
118-75-2	Chloranil	dyes, pigments, pesticides
87-86-5	Pentachlorophenol (PCP)	wood preserving, pesticides
107-06-2	Ethylene dichloride (EDC)	VC/PVC production, gasoline, paints and varnishes, metal degreasing, scouring compounds, organic synthesis, solvent, fumigant
75-01-4	Vinyl chloride (VC)	PVC manufacturing, adhesives
9002-86-2	Polyvinyl chloride (PVC)	plastic products
94-75-7	2,4-D	pesticides
1928-43-4	2,4-D Ester Herbicides	pesticides

Section 1.6. What Other Changes to the EPCRA Section 313 Reporting Requirements Apply to the Dioxin and Dioxin-like Compounds Category?

EPA has also made modifications and/or clarifications to certain reporting exemptions and requirements for the PBT chemicals that are subject to the lower reporting thresholds; this includes the dioxin and dioxin-like compounds category. Each of the changes as they apply to dioxin and dioxin-like compounds category is discussed in the following subsections.

Section 1.6.1. *De Minimis* Exemption

The *de minimis* exemption allows facilities to disregard certain minimal concentrations of toxic chemicals in mixtures or other trade name products they process or otherwise use when making threshold determinations and release and other waste management calculations.

EPA eliminated the *de minimis* exemption for the dioxin and dioxin-like compounds category. This means that facilities are required to include all amounts of dioxin and dioxin-like compounds in threshold determinations and release and other waste management calculations regardless of the concentration of the dioxin and dioxin-like compounds in mixtures or trade name products.

Section 1.6.2. Form A Exclusion

The “TRI Alternate Threshold for Facilities with Low Annual Reportable Amounts,” provides facilities otherwise meeting EPCRA section 313 reporting thresholds the option of reporting on Form A provided that they do not exceed 500 pounds for the total annual reportable amount for that chemical, and that their amounts manufactured or processed or otherwise used do not exceed one million pounds.

EPA has excluded the dioxin and dioxin-like compounds category from the “TRI Alternate Threshold for Facilities with Low Annual Reportable Amounts.” Therefore, submitting a Form A rather than a Form R is not an option for the dioxin and dioxin-like compounds category.

Section 1.6.3. Range Reporting

For facilities with total annual releases or off-site transfers of an EPCRA section 313 chemical of less than 1,000 pounds, EPA allows the amounts to be reported on the Form R either as an estimate or by using ranges.

EPA has eliminated range reporting for the dioxin and dioxin-like compounds category. This means that for those sections of the Form R for which range reporting is an option, the option cannot be used when reporting on the dioxin and dioxin-like compounds category. Thus facilities must report an actual number rather than a selected range.

Section 1.6.4. Data Precision

Facilities should report for the dioxin and dioxin-like compounds category at a level of precision supported by the accuracy of the underlying data and the estimation techniques on which the estimate is based. However, the smallest quantity that should be reported on the Form R for the dioxin and dioxin-like compounds category is 0.0001 grams (i.e., 100 micrograms).

Example: if the total quantity for section 5.2 of the Form R (i.e., Stack or point air emissions) is 0.00005 grams or less, then zero can be entered. If the total quantity is between 0.00005 and 0.0001 grams then 0.0001 grams can be entered or the actual number can be entered (e.g., 0.000075).

Section 2.0. GUIDANCE ON ESTIMATING ENVIRONMENTAL RELEASES OF DIOXIN AND DIOXIN-LIKE COMPOUNDS

Section 2.1. General Guidance

EPA is providing the following guidance to be used by facilities in estimating and reporting annual releases and other waste management quantities for the dioxin and dioxin-like compounds category. If you are not sure whether information in this guidance can be applied to the situation at your facility, then EPA should be consulted before using this guidance. The EPA contact for the emission factors and other estimation methods contained in this document is David Cleverly, National Center for Environmental Assessment (8623D), U.S. EPA, 1200 Pennsylvania Ave, NW, Washington, DC or e-mail at cleverly.david@epa.gov.

EPA supports the use of three different approaches for estimating annual releases of dioxin and dioxin-like compounds from facilities subject to reporting:

1. Use of actual facility-specific monitoring data
2. Use of facility-specific emission factors
3. Use of EPA default emission factors

In general EPA considers these three approaches to be hierarchical. In most situations, monitoring or directly measured data obtained at your facility provides the best and most accurate estimate of annual releases of dioxin and dioxin-like compounds. However, the facility must be able to document the adequacy and quality of the data in terms of sampling and laboratory methods used to ascertain the data. To be representative of annual releases of dioxin and dioxin-like compounds, the monitoring and sampling should have been taken under conditions representative of the facility's general operating and or production conditions. In the absence of such monitoring data two additional approaches can be considered.

- C First, facilities may use facility-specific emission factors that they believe are the best 'fit' to their facility. This means that the facility may use emission factors developed from the sampling and monitoring of dioxin and dioxin-like compounds at a similar facility. Reports of sampling emission and effluent streams should be collected and reviewed from facilities that are most similar in technology, design, operation, capacity, auxiliary fuels used, products produced, the manufacturing process, waste products generated, Industrial Classification Code, feedstocks used, and air/water pollution control systems. An important aspect in selecting an emission factor for a combustion process is temperature. A temperature inlet to the air pollution control device that is below 200° Celsius or above 450° Celsius will result in minimal stack release of dioxin and dioxin-like compounds. Therefore, in defining similarity of process, the facility operator is encouraged to examine, and then

match, the temperature reported at the facility for that you selected to be representative of potential emissions from your facility.

- C Second, facilities that cannot use either of these approaches should estimate their annual releases through the use of default emission factors provided by EPA in Chapter 4 of this guidance. Selection of more site-specific emission factors are preferred.

The owner/operator of the facility has the obligation of selecting one of these three approaches that is the most accurate reflection of the potential for releases of dioxin and dioxin-like compounds from the facility. The facility should be prepared to document the rationale employed in making such a determination. When documenting the annual releases and other waste management quantities of dioxin and dioxin-like compounds, the facility should clearly indicate which of these three approaches was used in deriving the estimate. A more detailed explanation of each of these approaches follows.

Section 2.1.1. Approach 1 - Use Actual Facility-specific Release Data

This approach allows the facility to estimate annual releases of dioxin and dioxin-like compounds to the air, water and land, as well as other waste management quantities, based on measured data derived at the facility. A facility may be required to perform monitoring under provisions of the Clean Air Act (CAA), the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), or other regulations. If this is the case, then these data should be available for developing release estimates. Data may have also been collected for your facility for compliance monitoring purposes associated with a state or federal permit. If only a small amount of direct measurement data are available or if you believe the monitoring data are not representative, you should determine if an alternative estimation method would give a more accurate result. With regard to the manner in which non-detects (ND) are reported, refer to Section 2.2.

Section 2.1.2. Approach 2 - Use Your Own Emission Factors

Emission factors are the fundamental tools in this guidance for estimating releases of dioxin and dioxin-like compounds. An emission factor is a representative value that is intended to relate the quantity of dioxin and dioxin-like compounds released to the open environment with a measure of industrial activity associated with the release. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, or duration of the activity emitting the contaminant. Examples of emission factors include: nanograms (ng) of dioxin and dioxin-like compounds emitted into air per kilogram (kg) of coal burned; picogram (pg) of dioxin and dioxin-like compounds discharged into surface water per liter (L) of wastewater; ng dioxin and dioxin-like compounds transferred to land disposal per kg of sludge produced at your facility. Emission factors facilitate estimation of environmental releases from various sources of releases of dioxin and dioxin-like compounds when the annual activity level of the facility is known. Your emission factor should be

assumed to be representative of long-term averages for your facility. The general equation for emission estimation is:

$$\text{Annual Release} = \text{Emission Factor} \times \text{Annual Activity Level}$$

$$R = EF \times A$$

where:

R = annual release of dioxin and dioxin-like compounds, (i.e., g / yr)

A = activity level or production rate, (e.g., kg of material processed per year)

EF = dioxin emission factor, (e.g., g dioxin released / kg material processed/ time)

EF is to represent the emission of dioxin and dioxin-like compounds into the open environment at the 'end-of-the-pipe'. The extent of completeness and detail of the emissions is determined by the information available from published references. Emissions from some processes are better documented than others. When electing to use this approach, the facility should make available documentation on the other facility(ies) engineering test reports that were evaluated and used in deriving your emission factors. The documentation should clarify why the other facility is a close analogy to your facility based on similarity of design, operations, feed stocks, end products, SIC code, manufacturing process, combustion process, and pollution control systems.

Section 2.1.3. Approach 3 - Use EPA Default Emission Factors

With this approach, EPA is providing tables of emission factors for specific sources, that, when multiplied by an appropriate measure of annual activity level at your facility, will result in an estimate of annual releases of the sum of dioxin and dioxin-like compounds (i.e., the 17 compounds of CDDs and CDFs) from your facility. Emission factors are used to calculate annual releases in situations in which the facility has not measured CDDs and CDFs in its effluents or emission streams. The EPA default emission factors were derived from the available monitoring data deemed to be representative of the source category (or segments of the source category that differ in configuration, fuel type, manufacturing process, feedstocks, pollution control systems, etc.). Implicit in the use of the default emission factors is the assumption that facilities with similar design and operating characteristics should have a similar potential for release of dioxin and dioxin-like compounds. The default emission factors are more accurately applied to an entire source category, because it is representative of the average emissions of all tested facilities in the category. This introduces a significant degree of uncertainty when applying the average emission factor to an individual facility, namely, that a portion of facilities within the industrial category will have emissions that are either above or below the average. However, in the absence of either monitoring data from your facility, or more accurate site-specific emission factors, EPA believes that these default emission factors can be used to make a reasonable estimation of releases.

The CDD and CDF emission factors in this guidance were developed from two primary references (both available in pdf format at: <http://www.epa.gov/tri/>):

- C EPA's Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-98/002Ab
- C The Inventory of Sources of Dioxin in the United States, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-98/002Aa

Section 2.2. Consideration of Non-detects

When detected in emissions and effluents from facilities, dioxin and dioxin-like compounds are found in minute quantities, e.g., one part-per trillion (1 ppt) or less, and as mixtures of dioxin and the dioxin-like compounds. Detection is with high resolution gas chromatography combined with high resolution mass spectrometry. For example, EPA Method 1613 (USEPA, 1994a) (used to quantify CDDs and CDFs in wastewater, solids, air, and tissue samples) can reliably detect these compounds at or below one part per trillion (i.e., 10 parts per quadrillion (ppq) in water; 1 ppt in solid waste). This presents a challenge in terms of interpretation of results in which a CDD/CDF compound is reported by the analytical laboratory as 'Not Detected' (shown as the abbreviation 'ND' on lab sheets).

Even with these extremely low levels of detectability with current laboratory methods, it is not possible to know with certainty if 'not detected' (ND) is actually zero (i.e., that dioxin and dioxin-like compounds are not present in the sample) or if dioxin and dioxin-like compounds really are present in the sample at some concentration below the minimal detection limit (MDL). The monitoring data and emission factors determined for your facility should be reported in a manner consistent with the methods and procedures that EPA has developed for determining if these compounds are present in various industrial processes. For example, EPA Method 1613 (USEPA, 1994a) indicates that laboratory results below the minimum detection level should be reported as not detected (ND) or as required by the regulatory authority. For purposes of threshold determinations and the reporting of releases and other waste management quantities for dioxin and dioxin-like compounds under EPCRA section 313, either with monitoring data, or by using the emission factor approach, non-detects are treated as 'zero' if that is how the method being used (e.g., Method 1613, Method 23, etc.) treats non-detects. However, facilities should use their best readily available information to report, so if a facility has better information than provided by these methods then that information should be used. For example, if a facility is not detecting a particular dioxin-like compound using a particular method but has information that shows that they should be detecting it then the facility should use this other information and it may be appropriate to estimate quantities using one half the detection limit.

If the method being used by a facility to detect dioxin and dioxin-like compounds is not an EPA approved method and the detection level being used is not as sensitive as those approved for use under EPA methods then EPA's EPCRA section 313 guidance with regard to non-detects should be followed. This guidance states that facilities must use reasonable judgement as to the presence and amount of a listed toxic chemical based on the best readily available information. An indication that a reportable chemical is below detection is not equivalent to stating that the chemical is not present. If the reportable toxic chemical is known to be present, a concentration equivalent to half the detection limit should be used. Facilities should not estimate releases solely on monitoring devices, they should also rely on their knowledge of specific conditions at the plant.

Section 3.0. EXAMPLES OF CALCULATING EMISSIONS TO THE AIR, WATER AND LAND

Environmental releases of dioxin and dioxin-like compounds occur to all media air, water and land. Dioxin and dioxin-like compounds are not intentionally manufactured, they are by-products of certain manufacturing and combustion processes, and are inadvertently formed during these processes. In this regard, dioxin releases cannot be determined by a mass balance of your facility. Rather you must resort to one of the three approaches listed in Section 2.0, above (direct measurements, or the two emission factor approaches). Section 4.0 gives EPA default emission factors for specific facilities falling within certain reporting facility SIC codes. The purpose of this section is to give examples of calculating emissions to air, water and land from your facility. In some examples the phrase “dioxin and dioxin-like compounds” may be abbreviated to “D&DLC” to save space.

Section 3.1. Approach 1 - Use Actual Facility-specific Release Data

Section 3.1.1. Example of Calculating Air Releases Using Stack Monitoring Data

Example: Stack testing has determined that dioxin and dioxin-like compounds are detected in the stack gases at your facility at a concentration of $10 \text{ E} - 09 \text{ g per dry standard cubic meter of gas (10 ng/dscm)}$. The moisture content in the stack is typically 10%. The stack gas velocity is typically 8.0 m/s. The diameter of the stack is 0.3 m. Calculate the annual air release of dioxin and dioxin-like compounds from the stack of your facility.

Step 1. Calculate volumetric flow of stack gas stream.

$$\text{Volumetric flow} = (\text{gas velocity}) \times \left[(p) \times (\text{internal stack diameter})^2 \div 4 \right]$$

$$\text{Volumetric flow} = (8.0 \text{ m} / \text{s}) \times \left[(p) \times (0.3\text{m})^2 \div 4 \right]$$

$$\text{Volumetric flow} = 0.6 \text{ m}^3 / \text{s}$$

Step 2. Correct volumetric flow for moisture content in stack gas stream

Stack gases may contain large amounts of water vapor. The concentration of the chemical in the exhaust is often presented on a ‘dry gas’ basis. For an accurate release rate, you must correct the stack or vent gas flow rate in Step 1 for the moisture content in your facility’s stack gas. This is done simply by multiplying the volumetric flow in Step 1 by the term (1 - fraction of water vapor). The dry gas volumetric flow rate can then be multiplied by the concentration of dioxin and dioxin-like compounds measured in the stack gases (see Step 3).

Dry volumetric flow = (volumetric flow) x (1 - fraction of water vapor)

Dry volumetric flow (corrected) = (0.6 m³ / s) x (1 - 0.10) = 0.5 m³ / s

Step 3. Estimate annual stack emissions to air.

$$R_{air} = C \times V \times CF \times H \times \{units\ conversion\ factor\}$$

Where:

R_{air} = Annual release of dioxin and dioxin-like compounds to air (g /yr)

C = Combustion flue gas concentration of D&DLC (ng/dry standard cubic meter)

V = Hourly Volumetric flow rate of combustion flue gas (dscm/hour) (20°C, 1 atm; adjusted to 7% O₂)

CF = Capacity factor, fraction of time that the facility operates on an annual basis (e.g., 0.85)

H = Total hours in a year (8,760 hr/yr)

$$R_{air} = \left(\frac{10\ ng}{dscm} \right) \times \left(\frac{0.5\ dscm}{s} \right) \times \left(\frac{3600\ s}{hr} \right) \times \left(\frac{8760\ hr}{yr} \right) \times (0.85) \times \left(\frac{g}{10^9\ ng} \right)$$

$$R_{air} = 0.13\ g / yr$$

Section 3.1.2. Example of Calculating Water Releases Using NPDES Monitoring Data

Example: Your facility is subject to NPDES permits for the discharge of dioxin and dioxin-like compounds into surface waters. You are required to conduct periodic monitoring of the effluent discharge from your facility. In this example, quarterly samples were taken to be analyzed for the content of dioxin and dioxin-like compounds. Each sample was an hourly, flowrate-based composite taken for one day to be representative of the discharge for that day. The total effluent volume for that day was also recorded. Your facility operates 350 days/year. The following data were collected on each sample day.

Quarter sample number	Discharge flow rate (10 ⁶ gal/day)	Dioxin and dioxin-like compounds concentration (picograms per liter (pg/L))
1	20	10
2	20	10
3	40	10
4	100	10

To calculate the amount of dioxin and dioxin-like compounds discharged on each sample day, the concentration of dioxin and dioxin-like compounds in the discharge is multiplied by the discharge flow rate for that day, as shown below for the first quarter sample.

Step 1: Calculate the amount of dioxin and dioxin-like compounds discharged per day from each day of sampling.

Amount of dioxin and dioxin-like compounds/day = (daily effluent flow rate) x (dioxin and dioxin-like compounds concentration in effluent). From the table above, the calculation of daily dioxin and dioxin-like compounds effluent discharge for the first sampling quarter is:

$$\text{First Quarter Discharge} = \left\{ \frac{10 \text{ pg}}{\text{L}} \right\} \times \left\{ \frac{1 \text{ g}}{10^{12} \text{ pg}} \right\} \times \left\{ \frac{3.8 \text{ L}}{\text{gal}} \right\} \times \left\{ \frac{20 \times 10^6 \text{ gal}}{\text{day}} \right\}$$

$$\text{First Quarter Discharge} = 0.00076 \text{ g dioxin and dioxin-like compounds / day}$$

Step 2: Find the average amount of dioxin discharged in effluent/day

Using the same equation, the second, third and forth quarter dioxin and dioxin-like compounds monitoring events are calculated to be 0.00076 g/day; 0.0015 g/day; and 0.038 g/day, respectively. Then the average daily dioxin and dioxin-like compounds discharge rate for all monitoring events at this facility is:

$$\text{Average daily discharge} = \left\{ \frac{0.00076 + 0.00076 + 0.0015 + 0.0038}{4 \text{ sampling periods}} \right\} \text{ g / day}$$

$$\text{Average daily dioxin and dioxin - like compounds discharge} = 0.0017 \text{ g / day}$$

Step 3 Calculate the annual discharge of dioxin to surface waters

Your facility operates 350 days/year. The estimated annual discharge of dioxin and dioxin-like compounds is calculated as follows:

$$\text{Annual Discharge of D\&DLC to Surface Water} = \left\{ \frac{350 \text{ day}}{\text{yr}} \right\} \times \left\{ \frac{0.0017 \text{ g}}{\text{day}} \right\}$$

$$\text{Annual Dioxin and Dioxin-like Compounds Discharge to Surface Water} = 0.6 \text{ g / yr}$$

Section 3.1.3. Example of Estimating Releases to Land

Under EPCRA section 313, the disposal of toxic chemicals in on-site landfills constitutes a release to land. Waste contaminated with dioxin and dioxin-like compounds may be placed in a RCRA subtitle C landfill for disposal. The following is an example of calculating the annual quantity of dioxin and dioxin-like compounds disposed in a RCRA subtitle C landfill.

Example: Land disposal of sludge. Your facility generates approximately 1 kg of dry sludge per 4000 L of wastewater treated at the facility's on-site industrial wastewater treatment plant. The facility operations produce approximately 100 million L of wastewater per day. Monitoring results indicate that the sludge, on average, contains approximately 3 ng dioxin and dioxin-like compounds per kg dry sludge produced. All of the sludge from your facility is placed in an on-site RCRA subtitle C landfill. The facility operates 350 days per year. What is the annual amount of dioxin and dioxin-like compounds released to land from your facility as a function of land disposal of the sludge contaminated with dioxin and dioxin-like compounds?

Step 1: Determine the amount of sludge produced per day from the wastewater treatment process.

$$\text{Total Sludge Generated} = \left\{ \frac{1 \text{ kg sludge}}{4000 \text{ L wastewater}} \right\} \times \left\{ \frac{1 \times 10^8 \text{ L wastewater}}{\text{day}} \right\}$$

$$\text{Total Sludge Generated} = 25,000 \text{ kg / day}$$

Step 2: Determine the amount of dioxin and dioxin-like compounds contained in the sludge produced each day.

$$\begin{aligned} \text{Total amount of D\&DLC in sludge} = \\ \text{Total sludge generated} \times \text{average D\&DLC concentration in sludge} \end{aligned}$$

$$\begin{aligned} \text{Total amount of D\&DLC in sludge} = \\ \left\{ \frac{25,000 \text{ kg sludge}}{\text{day}} \right\} \times \left\{ \frac{3 \text{ ng D\&DLC}}{\text{kg of sludge}} \right\} \times \left\{ \frac{\text{g}}{10^9 \text{ ng}} \right\} \end{aligned}$$

$$\text{Total amount of dioxin and dioxin-like compounds in sludge} = 0.000075 \text{ g / day}$$

Step 3 Calculate the annual release of dioxin and dioxin-like compounds to land based on annual days of operation per year

*Annual release of dioxin and dioxin - like compounds to land =
average daily D& DLC loading in sludge x total operating days per year.*

Annual release of dioxin and dioxin - like compounds to land =

$$\left\{ \frac{7.5 \times 10^{-5} \text{ g D\& DLC}}{\text{day}} \right\} \times \left\{ \frac{350 \text{ operating days}}{\text{year}} \right\}$$

Annual release of dioxin and dioxin - like compounds to land = 0.03 g / yr

Section 3.2. Examples of Estimating Releases Using Emission Factors

You have either developed your own facility-specific emission factors or have decided to use EPA's default emission factors (refer to Chapter 4.0; EPA Default Emission Factors) to estimate annual releases of dioxin and dioxin-like compounds from your facility to air, land and water. Emission factors (EF) relate potential release of dioxin and dioxin-like compounds to the activity level of your facility. The units vary according to the units of measure of activity level, but usually are weight per unit weight of production or weight per unit volume related to production. A common EF for combustion processes is ng dioxin and dioxin-like compounds per kg material combusted, processed, or produced. A common EF for point source effluent discharges into surface waters is pg dioxin and dioxin-like compounds per L of wastewater discharged. A common EF for RCRA waste generated that will be disposed is pg dioxin and dioxin-like compounds per kg of waste or sludge generated. The following serves as examples of how to make calculations of annual releases of dioxin and dioxin-like compounds using either your own chosen emission factors or EPA default emission factors. In either case, the procedures are the same.

Section 3.2.1. Example of Estimating Air Releases

Example: The emission factor that best fits your facility is 10 ng dioxin and dioxin-like compounds released from the stack per kg of materials processed. Each day your facility processes 25,000 kg of materials, and your facility operates 350 days per year. The emission factor is appropriate for your level of dioxin and dioxin-like compounds control. Estimate the annual release of dioxin and dioxin-like compounds from the stack of your facility.

Solution:

$$R_{air} = EF \times A$$

Where:

R_{air} = annual release of dioxin and dioxin-like compounds to air; (g / yr)

A = material processed annually; (kg/yr)

EF = dioxin and dioxin-like compounds emission factor; (ng/kg)

$$R_{air} = \left\{ \frac{25,000 \text{ kg materials}}{\text{day}} \right\} \times \left\{ \frac{350 \text{ days}}{\text{year}} \right\} \times \left\{ \frac{10 \text{ ng D\&DLC}}{\text{kg materials}} \right\} \times \left\{ \frac{\text{g}}{10^9 \text{ ng}} \right\}$$

$$R_{air} = 0.09 \text{ g dioxin and dioxin-like compounds / year}$$

Section 3.2.2. Example of Estimating Water Releases

Example: Your facility discharges 100 million gallons per day of treated wastewater into surface water. The emission factor you have found to be most appropriate for your facility is 10 pg dioxin and dioxin-like compounds per liter of wastewater discharged. The emission factor reflects the level of dioxin and dioxin-like compounds control that is occurring at your facility. Your facility operates 365 days each year. Estimate the annual release of dioxin and dioxin-like compounds to surface water.

Solution:

$$R_{water} = \left\{ \frac{100 \times 10^6 \text{ gal wastewater}}{\text{day}} \right\} \times \left\{ \frac{3.78 \text{ L}}{\text{gal}} \right\} \times \left\{ \frac{365 \text{ days}}{\text{yr}} \right\} \times \left\{ \frac{10 \text{ pg D\&DLC}}{\text{L wastewater}} \right\} \times \frac{\text{g}}{10^{12} \text{ pg}}$$

$$R_{water} = 1.4 \text{ g dioxin and dioxin-like compounds / yr}$$

Section 3.2.3. Example of Estimating Releases to Land

Example: In the example above, the wastewater treatment plant process generates 1 kg of dry sludge per 5000 L of wastewater treated. The wastewater treatment process removes 50 % of the dioxin and dioxin-like compounds from the wastewater prior to discharging wastewater into surface water. All of the sludge generated at your facility is placed in an on-site RCRA subtitle C landfill. Calculate how much dioxin and dioxin-like compounds are released to land at your facility.

Step 1. Determine the amount of sludge generated each day at your facility.

Sludge generated = sludge generation rate per L wastewater x wastewater per day

$$Sludge\ generated = \left\{ \frac{1\ kg\ sludge}{5000\ L\ wastewater} \right\} \times \left\{ \frac{3.78 \times 10^8\ L\ wastewater}{day} \right\}$$

$$Sludge\ generated = 7.56 \times 10^4\ kg / day$$

Step 2. Estimate the Emission Factor (EF) for dioxin and dioxin-like compounds in the sludge

If it is assumed that all the dioxin and dioxin-like compounds are removed from the wastewater during the treatment process is contained in the sludge generated from the wastewater treatment process, then the EF for sludge can be calculated as a function of dioxin and dioxin-like compounds removal efficiency from the wastewater. Thus the EF for dioxin and dioxin-like compounds in wastewater times the removal efficiency gives an approximate indication of the dioxin and dioxin-like compounds EF for sludge at your facility. In the following calculation, assume the density of sludge = 500 g/ L.

$$EF_{sludge} = [EF_{wastewater} \times \{1 - \text{fraction D\&DLC removed}\}] \times (\text{density of sludge})^{-1} \times \text{units conversion factors}$$

$$EF_{sludge} = \left[\left\{ \frac{10\text{pg D\&DLC}}{L\ wastewater} \right\} \times \{1-.5\} \right] \times \left\{ \frac{1\ L}{500\ g} \right\} \times \left\{ \frac{10^3\ g}{kg} \right\}$$

$$EF_{sludge} = 10\ \text{pg dioxin and dioxin-like compounds} / kg$$

Step 3. Calculate the annual release of dioxin and dioxin-like compounds to land

$$R_{land} = \left(\frac{\text{quantity sludge}}{day} \right) \times \{EF_{sludge}\} \times \left\{ \frac{\text{operating days}}{year} \right\}$$

$$R_{land} = \left\{ \frac{7.56 \times 10^4\ kg\ sludge}{day} \right\} \times \left\{ \frac{10\ \text{pg D\&DLC}}{kg\ sludge} \right\} \times \left\{ \frac{g}{10^{12}\ \text{pg}} \right\} \times \left\{ \frac{365\ days}{year} \right\}$$

$$R_{land} = 3 \times 10^{-4}\ g\ dioxin\ and\ dioxin\ -\ like\ compounds / year$$

Section 4.0. FACILITY-SPECIFIC EPA DEFAULT EMISSION FACTORS

EPA is providing default emission factors for facilities to use, at their discretion, in reporting annual releases and other waste management quantities of dioxin and dioxin-like compounds. You are encouraged, however, to use site-specific information on releases from your facility. EPA recognizes that emissions and environmental release data are not available in most cases. This guidance is providing a series of 'look-up' tables to assist you in meeting the requirements of annually reporting releases of dioxin and dioxin-like compounds. Information is limited to those source categories for which EPA believes sufficient information is available to develop default emission factors that can be used to make reasonable estimations of releases. The documentation for the derivation of the emission factors can be found in two EPA references (both available in pdf format at: <http://www.epa.gov/tri/>):

- EPA's Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-98/002Ab
- The Inventory of Sources of Dioxin in the United States, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-98/002Aa

In applying these default emission factors, you are encouraged to read the summary description provided for the facilities that were used to derive the default emission factors. Facilities should use those emission factors that match as closely as practical the class type and pollution control systems of your facility. Although EPA's default emission factors are arithmetic averages of environmental releases from tested facilities, EPA recognizes that these tested facilities may not be an ideal match to your facility. The decision to use EPA default emission factors is best left to the operator of the facility. This guidance is intentionally made to be flexible in the use and selection of emissions of dioxin and dioxin-like compounds that are most representative of emissions from your facility. All of the emission factors contained in the tables in this section are for controlled conditions.

In all of the emission factors tables the emission factor for the dioxin and dioxin-like compounds category is equal to the sum of the emission factors for the 7 dibenzo-p-dioxins (CDDs) covered by the category and the 10 dibenzofurans (CDFs) covered by the category. Thus,

$$3 \text{ Dioxin and dioxin-like compounds} = 3 \text{ CDDs} + 3 \text{ CDFs}$$

Section 4.1. Pulp and Paper Mills

Section 4.1.1. Applicability

The following SIC Codes are included within this category:

I. SIC Code 2611 Pulp Mills: Establishments primarily engaged in manufacturing pulp from wood or from other materials, such as rags, linters, wastepaper, and straw. Establishments engaged in integrated logging and pulp mill operations are classified according to the primary products shipped. Establishments engaged in integrated operations of producing pulp and manufacturing paper, paperboard, or products thereof are classified in Industry 2621 if primarily shipping paper or paper products; in Industry 2631 if primarily shipping paperboard or paperboard products; and in Industry 2611 if primarily shipping pulp.

Pulp mills

Pulp: soda, sulfate, sulfite, groundwood, rayon, and semichemical

Wood pulp

II. 2621 Paper Mills: Establishments primarily engaged in manufacturing paper from woodpulp and other fiber pulp, and which may also manufacture converted paper products. Establishments primarily engaged in integrated operations of producing pulp and manufacturing paper are included in this industry if primarily shipping paper or paper products. Establishments primarily engaged in manufacturing converted paper products from purchased paper stock are classified in Industry Group 265 or Industry Group 267.

Section 4.1.2. Emission Factors for Releases to Water

On April 15, 1998 and August 7, 1998, EPA promulgated final effluent standards (Federal Register, 1998) under the Clean Water Act for pulp and paper mills (63 FR 18504-18751, and 63 FR 42238-42240). Mills subject to regulation are pulp mills and integrated mills (mills that manufacture pulp and paper/paperboard), that chemically pulp wood fiber (using kraft, sulfite, soda, or semi-chemical methods); that produce pulp secondary fiber; pulp non-woody fiber; and mechanically pulp wood fiber. In reporting releases of dioxin and dioxin-like compounds to surface waters, the facility may use the EPA default emission factors in Table 4-1.

Table 4-1. Average Emission Factors (pg/L) for Estimating Wastewater Discharges of Dioxin and Dioxin-like Compounds into Surface Water From Bleached Paper grade Kraft and Soda Mills

CDD	Mean Emission Factor (pg/L)	CDF	Mean Emission Factor (pg/L)
2,3,7,8-TCDD	1.2	2,3,7,8-TCDF	2.3
1,2,3,7,8-PeCDD	0	1,2,3,7,8-PeCDF	0
1,2,3,4,7,8-HxCDD	0	2,3,4,7,8-PeCDF	0
1,2,3,6,7,8-HxCDD	0	1,2,3,4,7,8-HxCDF	0
1,2,3,7,8,9-HxCDD	0	1,2,3,6,7,8-HxCDF	0
1,2,3,4,6,7,8-HpCDD	3.2	1,2,3,7,8,9-HxCDF	0
1,2,3,4,6,7,8,9-OCDD	99.0	2,3,4,6,7,8-HxCDF	0
		1,2,3,4,6,7,8-HpCDF	0
		1,2,3,4,7,8,9-HpCDF	0
		1,2,3,4,6,7,8,9-OCDF	0
3 CDDs	103.4 pg /L	3 CDFs	2.3 pg /L
3 Dioxin and dioxin-like compounds*			
	105.7 pg/L		

Source: Gillespie, 1997; *3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.1.3. Emission Factors for Releases to Land

The conventional wastewater treatment of effluents results in the generation of wastewater sludge. If your facility applies the sludge to land, or places it in a RCRA subtitle C landfill for disposal, then the default emission factors in Table 4-2 apply:

Table 4-2. Average Emission Factors (ng/kg) for Land Disposal of Dioxin and Dioxin-like Compounds in Wastewater Sludge from Bleached Paper Grade Kraft and Soda Mills

CDD	Mean Emission Factor (ng/kg)	CDF	Mean Emission Factor (ng/kg)
2,3,7,8-TCDD	0.8	2,3,7,8-TCDF	6.2
1,2,3,7,8-PeCDD	0	1,2,3,7,8-PeCDF	0
1,2,3,4,7,8-HxCDD	0.5	2,3,4,7,8-PeCDF	0.5
1,2,3,6,7,8-HxCDD	2.3	1,2,3,4,7,8-HxCDF	0
1,2,3,7,8,9-HxCDD	1.6	1,2,3,6,7,8-HxCDF	0
1,2,3,4,6,7,8-HpCDD	41.4	1,2,3,7,8,9-HxCDF	0
1,2,3,4,6,7,8,9-OCDD	445.0	2,3,4,6,7,8-HxCDF	0.5
		1,2,3,4,6,7,8-HpCDF	1.2
		1,2,3,4,7,8,9-HpCDF	0
		1,2,3,4,6,7,8,9-OCDF	0
3 CDDs	491.6 ng /kg	3 CDFs	8.4 ng /kg
3 Dioxin and dioxin-like compounds*			
	500 ng/kg		

Source: Gillespie, 1997; *3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.1.4. Releases to Air

Wood waste and bark produced from processing timber at bleached chemical pulp mills are burned in the facilities' bark burners (NCASI, 1995). This wood waste can produce CDDs/CDFs during combustion. If your facility burns wood waste and bark, then the default emission factors in Table 4-3 apply:

Table 4-3. Average Emission Factors (ng/kg) for Air Releases of Dioxin and Dioxin-like Compounds from the Combustion of Wood Waste and Bark at Bleached Paper Grade Kraft and Soda Mills

CDD	Mean Emission Factor (ng/kg)	CDF	Mean Emission Factor (ng/kg)
2,3,7,8-TCDD	0.005	2,3,7,8-TCDF	0.104
1,2,3,7,8-PeCDD	0.005	1,2,3,7,8-PeCDF	0.022
1,2,3,4,7,8-HxCDD	0.012	2,3,4,7,8-PeCDF	0.020
1,2,3,6,7,8-HxCDD	0.050	1,2,3,4,7,8-HxCDF	0.070
1,2,3,7,8,9-HxCDD	0.035	1,2,3,6,7,8-HxCDF	0.043
1,2,3,4,6,7,8-HpCDD	0.300	1,2,3,7,8,9-HxCDF	0.036
1,2,3,4,6,7,8,9-OCDD	1.200	2,3,4,6,7,8-HxCDF	0.004
		1,2,3,4,6,7,8-HpCDF	0.274
		1,2,3,4,7,8,9-HpCDF	0.081
		1,2,3,4,6,7,8,9-OCDF	0.187
3 CDDs	1.6 ng /kg	3 CDFs	0.84 ng /kg
3 Dioxin and dioxin-like compounds*			
	2.4 ng/kg		

Source: NCASI (1995); *3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.2. Secondary Smelting and Refining of Nonferrous Metals

Section 4.2.1. Applicability

SIC Code 3341, Secondary Smelting and Refining of Nonferrous Metals, include establishments primarily engaged in recovering nonferrous metals and alloys from new and used scrap and or in producing alloys from purchased refined metals. This industry includes establishments engaged in both the recovery and alloying of precious metals. Plants engaged in the recovery of tin through secondary smelting and refining, as well as by chemical processes, are included in this industry. Establishments primarily engaged in assembling, sorting, and breaking up scrap metal, without smelting and refining, are classified in Wholesale Trade, Industry 5093. Applicable facilities include:

- C Aluminum smelting and refining, secondary
- C Copper smelting and refining, secondary
- C Lead smelting and refining, secondary
- C Nonferrous metal smelting and refining, secondary

- C Recovering and refining of nonferrous metals
- C Secondary refining and smelting of nonferrous metals

Section 4.2.2. Secondary Aluminum Smelters

Stack tests from four secondary aluminum facilities (described below) were used by EPA to derive mean air emission factors of dioxin and dioxin-like compounds. Secondary aluminum smelters reclaim aluminum from scrap containing aluminum. This recycling involves two processes -- pre-cleaning and smelting. Both processes may produce CDD/CDF emissions.

Pre-cleaning processes involve sorting and cleaning scrap to prepare it for smelting. Cleaning processes that may produce CDD/CDF emissions use heat to separate aluminum from contaminants and other metals; these techniques are roasting and sweating. Roasting uses rotary dryers with a temperature high enough to vaporize organic contaminants, but not high enough to melt aluminum. An example of roasting is the delacquering and processing of used beverage cans. Sweating involves heating aluminum-containing scrap metal to a temperature above the melting point of aluminum, but below the melting temperature of other metals such as iron and brass. The melted aluminum trickles down and accumulates in the bottom of the sweat furnace and is periodically removed (U.S. EPA, 1997).

After pre-cleaning, the treated aluminum scrap is smelted and refined. This usually takes place in a reverberatory furnace. Once smelted, flux is added to remove impurities. The melt is "demagged" to reduce the magnesium content of the molten aluminum by the addition of chlorine gas. The molten aluminum is transferred to a holding furnace and alloyed to final specifications (U.S. EPA, 1997).

CDD/CDF emissions to air have been measured at six U.S. secondary aluminum operations. Four facilities were tested in 1995 and two facilities were tested in 1992. Three of the four 1995 tests were conducted by EPA in conjunction with The Aluminum Association for the purpose of identifying emission rates from facilities with potentially maximum achievable control technology (MACT)-grade operations and air pollution control device (APCD) equipment; the other test performed in 1995 (U.S. EPA, 1995) was performed by EPA. Two facilities tested by the California Air Resources Board (CARB) in 1992 were reported in two confidential reports.

The first facility tested in 1995 was a top charge melt furnace (Advanced Technology Systems, Inc., 1995). During testing, the charge material to the furnace was specially formatted to contain no oil, paint, coatings, rubber, or plastics (other than incidental amounts). The CDD/CDF emissions from such a clean charge, 0.26 ng toxic equivalents (TEQ)/kg charge material, would be expected to represent the low end of the normal industry range.

The second facility operates a sweat furnace to pre-clean the scrap and a reverberatory furnace to smelt the pre-cleaned aluminum (U.S. EPA, 1995). Stack emissions are controlled by

an afterburner operated at 1,450° F.

The third facility employs a crusher/roasting dryer as a pre-cleaning step followed by a reverberatory furnace (Galson Corporation, 1995). The emissions from the two units are vented separately. The exhaust from the crusher/dryer is treated with an afterburner and a baghouse. The exhaust from the furnace passes through a baghouse with lime injection.

The fourth facility operates a scrap roasting dryer followed by a sidewall reverberatory furnace (Envisage Environmental, Inc., 1995). The emissions from the two units are vented separately. Exhaust from the dryer passes through an afterburner and a lime-coated baghouse. The exhaust from the furnace passes through a lime-coated baghouse.

Two facilities tested by CARB in 1992 and reported in two confidential reports (CARB, 1992a, as reported in U.S. EPA, 1997; CARB, 1992b, as reported in U.S. EPA, 1997) were reported to have TEQ emission factors of 52.2 and 21.7 ng TEQ/kg scrap aluminum consumed. One facility was equipped with a venturi scrubber; the other was assumed in U.S. EPA (1997) to be uncontrolled. Table 4-4 presents congener-specific average stack gas emission factors (ng/kg scrap aluminum processed).

Table 4-4. Average Emission Factors (ng/kg scrap aluminum processed) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Secondary Aluminum Smelters

CDD	Mean Emission Factor (ng / kg)	CDF	Mean Emission Factor (ng / kg)
2,3,7,8-TCDD	0.94	2,3,7,8-TCDF	15.09
1,2,3,7,8-PeCDD	2.70	1,2,3,7,8-PeCDF	10.91
1,2,3,4,7,8-HxCDD	1.93	2,3,4,7,8-PeCDF	19.10
1,2,3,6,7,8-HxCDD	2.89	1,2,3,4,7,8-HxCDF	23.44
1,2,3,7,8,9-HxCDD	3.08	1,2,3,6,7,8-HxCDF	14.87
1,2,3,4,6,7,8-HpCDD	12.83	1,2,3,7,8,9-HxCDF	4.34
1,2,3,4,6,7,8,9-OCDD	4.90	2,3,4,6,7,8-HxCDF	14.86
		1,2,3,4,6,7,8-HpCDF	17.53
		1,2,3,4,7,8,9-HpCDF	7.54
		1,2,3,4,6,7,8,9-OCDF	23.77
3 CDDs	29.3 ng /kg	3 CDFs	151.5 ng /kg
3 Dioxin and dioxin-like compounds*			
	180.8 ng/kg		

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.2.3. Secondary Lead Smelters

The secondary lead smelting industry produces elemental lead through the chemical reduction of lead compounds in a high temperature furnace (1,200 to 1,260° C). Smelting is performed in reverberatory, blast, rotary, or electric furnaces. Blast and reverberatory furnaces are the most common types of smelting furnaces used by the 23 facilities that comprise the current secondary lead smelting industry in the United States. Of the 45 furnaces at these 23 facilities, 15 are reverberatory furnaces, 24 are blast furnaces, five are rotary furnaces, and one is an electric furnace. The one electric furnace and 11 of the 24 blast furnaces are co-located with reverberatory furnaces, and most share a common exhaust and emissions control system (U.S. EPA, 1994b).

Furnace charge materials consist of lead-bearing raw materials, lead-bearing slag and drosses, fluxing agents (blast and rotary furnaces only), and coke. Scrap motor vehicle lead-acid batteries represent about 90 percent of the lead-bearing raw materials at a typical lead smelter. Fluxing agents consist of iron, silica sand, and limestone or soda ash. Coke is used as fuel in blast furnaces and as a reducing agent in reverberatory and rotary furnaces. Organic emissions from co-located blast and reverberatory furnaces are more similar to the emissions of a reverberatory furnace than the emissions of a blast furnace (U.S. EPA, 1994b).

Historically, many lead-acid batteries contained PVC plastic separators between the battery grids. These separators are not removed from the lead-bearing parts of the battery during the battery breaking and separation process. When the PVC is burned in the smelter furnace, the chlorine atoms are released as HCl, Cl₂, and chlorinated hydrocarbons (Federal Register, 1995d). The source of CDDs/CDFs at secondary lead smelters is the PVC separator (U.S. EPA, 1995c). In 1990, about 1 percent of scrap batteries processed at lead smelters contained PVC separators. In 1994, less than 0.1 percent of scrap batteries contained PVC separators. This trend is expected to continue because no U.S. manufacturer of lead-acid automotive batteries currently uses PVC in production (U.S. EPA, 1995c; Federal Register, 1995d).

The total current annual production capacity of the 23 companies currently comprising the U.S. lead smelting industry is 1.36 million metric tons. Blast furnaces not co-located with reverberatory furnaces account for 21 percent of capacity (or 0.28 million metric tons). Reverberatory furnaces and blast and electric furnaces co-located with reverberatory furnaces account for 74 percent of capacity (or 1.01 million metric tons). Rotary furnaces account for the remaining 5 percent of capacity (or 0.07 million metric tons). Actual production volume statistics by furnace type are not available. However, if it is assumed that the total actual production volume of the industry, 0.97 million metric tons in 1995 (U.S. Geological Survey, 1997a) and 0.72 million metric tons in 1987 (U.S. EPA, 1994a), are reflective of the production capacity breakdown by furnace type, then the estimated actual production volumes of blast furnaces (not co-located), reverberatory and co-located blast/electric and reverberatory furnaces, and rotary furnaces were 0.20, 0.72, and 0.05 million metric tons, respectively, in 1995, and 0.15, 0.53, and 0.04 million metric tons, respectively, in 1987. In 1987, the industry consisted of 24 facilities.

CDD/CDF emission factors can be estimated for lead smelters based on the results of emission tests performed by EPA at three smelters (a blast furnace, a co-located blast/reverberatory furnace, and a rotary kiln furnace) (U.S. EPA, 1992e; 1995d; 1995e). The air pollution control systems at the three tested facilities consisted of both baghouses and scrubbers. Congener-specific measurements were made at the exit points of both APCD exit points at each facility. Table 4-5 presents the congener emission factors from the baghouse and the scrubber for each site. Although

Table 4-5. Average Emission Factors (ng/kg) for Estimating Annual Releases of Dioxin and Dioxin-Like Compounds from Secondary Lead Smelters

CDD/CDF Congener	Blast Furnace (ng/kg lead produced)		Blast/reverb (ng/kg lead produced)		Rotary kiln (ng/kg lead produced)	
	<i>before scrubber</i>	<i>after scrubber</i>	<i>before scrubber</i>	<i>after scrubber</i>	<i>before scrubber</i>	<i>after scrubber</i>
2,3,7,8-TCDD	2.11	0.25	0.00	0.00	0.10	0.24
1,2,3,7,8-PeCDD	0.99	0.03	0.00	0.00	0.01	0.00
1,2,3,4,7,8-HxCDD	0.43	0.00	0.00	0.00	0.00	0.00
1,2,3,6,7,8-HxCDD	0.99	0.03	0.00	0.00	0.00	0.00
1,2,3,7,8,9-HxCDD	1.55	0.03	0.00	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDD	2.06	0.08	0.10	0.06	0.00	0.22
1,2,3,4,6,7,8,9-OCDD	1.40	0.39	0.57	0.55	0.24	2.41
3 CDDs	9.53	0.81	0.67	0.61	0.35	2.87
2,3,7,8-TCDF	8.73	0.93	1.46	0.49	0.40	1.20
1,2,3,7,8-PeCDF	3.88	0.43	0.24	0.02	0.14	0.40
2,3,4,7,8-PeCDF	6.65	0.36	0.31	0.00	0.14	0.46
1,2,3,4,7,8-HxCDF	5.83	0.37	0.63	0.00	0.11	0.27
1,2,3,6,7,8-HxCDF	1.67	0.11	0.19	0.00	0.02	0.10
1,2,3,7,8,9-HxCDF	0.11	0.00	0.00	0.00	0.04	0.13
2,3,4,6,7,8-HxCDF	2.06	0.11	0.15	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDF	2.34	0.19	0.48	0.00	0.03	0.13
1,2,3,4,7,8,9-HpCDF	0.63	0.06	0.00	0.00	0.00	0.00
1,2,3,4,6,7,8,9-OCDF	1.39	0.18	0.29	0.00	0.00	0.00
3 CDFs	33.29	2.74	3.75	0.51	0.88	2.69
3 Dioxin and dioxin-like compounds*	42.82	3.55	4.42	1.12	1.23	5.56

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

all 23 smelters employ baghouses, only 9 employ scrubber technology. Facilities that employ scrubbers account for 14 percent of the blast furnace (not co-located) production capacity, 52 percent of the reverberatory and co-located furnace production capacity, and 57 percent of the rotary furnace production capacity. From the reported data, congener-specific CDD/CDF emission factors (ng /kg lead processed) for each of the three furnace configurations are presented in Table 4-5. The range reflects the presence or absence of a scrubber. Note that calculations using emission factors before scrubbers would apply towards threshold calculations since this represents amounts that have been manufactured. They can also be used to estimate the amounts that a scrubber has removed and then the amounts removed, depending on how the scrubber material is handled, should be reported in the appropriate section of the Form R.

As discussed earlier in this section, the PVC separators used historically in lead-acid batteries are believed to be the source of the CDD/CDFs observed in emissions from secondary lead smelters. PVC separators are no longer used in the United States in the manufacture of lead-acid batteries, and less than 0.1 percent of the scrap batteries in 1994 contained PVC separators (U.S. EPA, 1995c; Federal Register, 1995c). EPA predicts that by the time existing smelters demonstrate compliance in 1997 with the National Emission Standards for Hazardous Air Pollutants (NESHAP) for secondary lead smelters promulgated by EPA (Federal Register, 1995c), batteries containing PVC will only be present in the scrap battery inventory in trace amounts, resulting at most, in only trivial amounts of HCl or Cl₂ air emissions.

Section 4.2.4. Secondary Copper Smelters/Refiners

Secondary copper smelting is part of the scrap copper, brass, and bronze reprocessing industry. Brass is an alloy of copper and zinc; bronze is an alloy of copper and tin. Facilities in this industry fall into three general classifications: secondary smelting, ingot making, and remelting. Similar process equipment may be used at all three types of facilities, so that the distinguishing features are not immediately apparent (U.S. EPA, 1994c).

The feature that distinguishes secondary smelters from ingot makers and remelters is the extent to which pyrometallurgical purification is performed. A typical charge at a secondary smelter may contain from 30 to 98 percent copper. The secondary smelter upgrades the material by reducing the quantity of impurities and alloying materials, thereby increasing the relative concentration of copper. This degree of purification and separation of the alloying constituents does not occur at ingot makers and remelters. Feed material to a secondary copper smelter is a mixture of copper-bearing scrap comprised of such scrap as tubing, valves, motors, windings, wire, radiators, turnings, mill scrap, printed circuit boards, telephone switching gear, and ammunition casings. Non-scrap items like blast furnace slags and drosses from ingot makers or remelters may represent a portion of the charge. The secondary smelter operator uses a variety of processes to separate the alloying constituents. Some purify the scrap in the reductive atmosphere of a blast furnace. The charge may be subsequently purified in the oxidizing atmosphere of a converter. Other secondary

smelters perform all purification by oxidation in top-blown rotary converters or in reverberatory furnaces (U.S. EPA, 1994c).

The ingot makers blend and melt scrap copper, brass, and bronze of various compositions to produce a specification brass or bronze ingot. When necessary, the ingot makers add ingots of other metals (e.g., zinc or tin) to adjust the metallurgy of the final product. The feed materials for ingot makers contain relatively high amounts of copper. Examples of feed materials include copper tubing, valves, brass and bronze castings, ammunition shell casings, and automobile radiators. "Fire-refined" anode copper or cathode copper may also be charged. Items such as motors, telephone switchboard scrap, circuit board scrap, and purchased slags are not used by ingot makers. The reductive step (melting in a reducing atmosphere, as in a blast furnace) that some secondary smelters employ is not used by ingot makers. Ingot makers do, however, use some of the other types of furnaces used by secondary smelters, including direct-fired converters, reverberatory furnaces, and electric induction furnaces (U.S. EPA, 1994c).

Remelting facilities do not conduct any substantial purification of the incoming feeds. These facilities typically just melt the charge and cast or extrude a product. The feeds to a remelter are generally alloy material of approximately the desired composition of the product (U.S. EPA, 1994c).

Stack emissions of CDDs/CDFs from a secondary copper smelter were measured by EPA during 1984/1985 as part of the National Dioxin Study (U.S. EPA, 1987). The facility chosen for testing was estimated to have "high" potential for CDD/CDF emissions due to the abundance of chlorinated plastics in the feed. This facility ceased operations in 1986. The tested facility was chosen for testing by EPA because the process technology and air pollution control equipment in place were considered typical for the source category. Copper and iron-bearing scrap were fed in batches to a cupola blast furnace, which produced a mixture of slag and black copper. Four to five tons of metal-bearing scrap were fed to the furnace per charge, with materials typically being charged 10 to 12 times per hour. Coke fueled the furnace, and represented approximately 14 percent by weight of the total feed. During the stack tests, the feed consisted of electronic telephone scrap and other plastic scrap, brass and copper shot, iron-bearing copper scrap, precious metals, copper bearing residues, refinery by-products, converter furnace slag, anode furnace slag, and metallic floor cleaning material. The telephone scrap comprised 22 percent by weight of the feed and was the only scrap component that contained plastic materials. Oxygen enriched combustion air for combustion of the coke was blown through tuyeres at the bottom of the furnace. At the top of the blast furnace were four natural gas-fired afterburners to aid in completing combustion of the exhaust gases. Fabric filters controlled particulate emissions, and the flue gas then was discharged into a common stack. The estimated emission factors derived for this site are presented in Table 4-6. The emission factors are based on the total weight of scrap fed to the furnace.

In 1992, stack testing of the blast furnace process stack emissions of a secondary smelter located in Philadelphia, Pennsylvania (Franklin Smelting and Refining Co.), was conducted by Applied Geotechnical & Environmental Services Corporation (AGES, 1992). Similar to the facility tested by EPA in 1984/1985, this facility processed low purity copper-bearing scrap, telephone switch gear, and slags, as well as higher copper content materials (U.S. EPA, 1994c). The facility used a blast (cupola-type) furnace coupled with a pair of rotary converters to produce blister copper. The blast furnace used coke as both the fuel and the agent to maintain a reducing atmosphere. The black copper/slag mixture from the blast furnace was charged to the rotary converters for further refining with the aid of oxygen, sand, and oak logs (AGES, 1992; U.S. EPA, 1994c). The APCD equipment installed on the blast furnace included an afterburner, cooling tower, and baghouse. The estimated emission factors derived for this site from the results in AGES (1992) are presented in Table 4-6. The emission factors are based on the total weight of scrap fed to the blast furnace.

In 1991, stack testing of the rotary furnace stack emissions of a secondary smelter located in Alton, Illinois (Chemetco, Inc.) was conducted by Sverdrup Corp. (1991). The Chemetco facility uses four tap down rotary (i.e., oxidizing) furnaces. Furnace process gas emissions are controlled by a primary quencher and a venturi scrubber. The feed is relative high purity copper scrap containing minimal plastics, if any. The same manufacturing process and APCD equipment were in place in 1987 and 1995 (U.S. EPA, 1994c). Because this facility operated under oxidizing rather than reducing conditions and processes relatively high purity scrap, the potential for CDD/CDF formation and release is expected to be dramatically different than that of the two tested facilities reported above. The estimated emission factors derived for this site from the results in Sverdrup (1991) are presented in Table 4-6.

In 1987, there were four secondary copper smelters in operation: Franklin Smelting and Refining Co. (Philadelphia, PA), Chemetco (Alton, IL), Southwire Co. (Carrollton, GA), and a facility located in Gaston, SC, that was owned by American Telephone and Telegraph (AT&T) until 1990 when it was purchased by Southwire Co. In 1987, estimated smelter capacities were 13,600,000 kg for the Franklin Smelting and Refining Co. facility, 120,000,000 kg for the Chemetco facility, 48,000,000 kg for the Southwire Co. facility, and 85,000,000 kg for the AT&T facility (Edelstein, 1999). In 1995, only three of these four facilities were in operation. The AT&T facility was closed in January of 1995. The Franklin facility subsequently ceased operations in August 1997. Estimated smelter capacities in 1995 were 16,000,000 kg for the Franklin Smelting and Refining Co. facility, 135,000,000 kg for the Chemetco facility, and 92,000,000 kg for the Southwire Co. facility (Edelstein, 1999).

Although little research has been performed to define the CDD/CDF formation mechanism(s) in secondary copper smelting operations, two general observations have been made (Buekens et al., 1997). The presence of chlorinated plastics in copper scraps used as feed to the smelters is believed to increase the CDD/CDF formation. Second, the reducing or pyrolytic conditions in blast furnaces can lead to high CDD/CDF concentrations in the furnace process

Table 4-6. CDD/CDF Emission Factors for Secondary Copper Smelters

Congener/Congener Group	Mean EPA Tier 4 Emission Factor ^{a,b} (ng/kg scrap feed)	Franklin Smelting Facility Mean Emission Factor ^c (ng/kg scrap feed)	Chemetco Smelting Facility Mean Emission Factor ^d (ng/kg scrap feed)
2,3,7,8-TCDD	127	227	ND (0.05)
1,2,3,7,8-PeCDD	NR	846	0.21
1,2,3,4,7,8-HxCDD	NR	1,476	0.39
1,2,3,6,7,8-HxCDD	NR	1,746	0.70
1,2,3,7,8,9-HxCDD	NR	2,132	1.26
1,2,3,4,6,7,8-HpCDD	NR	17,065	8.95
1,2,3,4,6,7,8,9-OCDD	1,350	55,668	22.45
3 CDDs	1,477	79,160	33.96
2,3,7,8-TCDF	2,720	4,457	2.11
1,2,3,7,8-PeCDF	NR	9,455	1.47
2,3,4,7,8-PeCDF	NR	5,773	2.63
1,2,3,4,7,8-HxCDF	NR	70,742	7.30
1,2,3,6,7,8-HxCDF	NR	20,524	2.15
1,2,3,7,8,9-HxCDF	NR	5,362	4.06
2,3,4,6,7,8-HxCDF	NR	12,082	0.27
1,2,3,4,6,7,8-HpCDF	NR	37,251	11.48
1,2,3,4,7,8,9-HpCDF	NR	7,570	2.74
1,2,3,4,6,7,8,9-OCDF	2,520	82,192	21.61
3 CDFs	5,240	255,408	55.82
3 Dioxin and dioxin-like compounds*	6,717	334,568	89.78

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Notes:

NR = Not reported.

ND = Not detected (value in parenthesis is the emission at the detection limit).

^a No nondetected values were reported for 2,3,7,8-TCDD, 2,3,7,8-TCDF, or any congener group in the three test runs.^b Source: U.S. EPA (1987a).^c Source: AGES (1992).^d Source: Sverdrup (1991).

gases. As noted in the discussion on emission data above, two of the U.S. facilities which have been tested (i.e., U.S. EPA, 1987; AGES, 1992) each had these characteristics. Both processed low-purity scrap containing significant quantities of plastics and both facilities used blast furnaces. The APCD equipment at both facilities consisted of an afterburner, cooling tower (Franklin facility only), and a baghouse (U.S. EPA, 1994c). The other tested U.S. facility (i.e., Sverdrup, 1991) utilizes oxidizing rather than reducing conditions and processes relatively high purity scrap.

The facility in Gaston, SC, was in operation during 1987, but not in 1995. Prior to 1990, when this facility was owned by AT&T, a great deal of high plastics content scrap (such as whole telephones) was processed by the plant. This high plastics content scrap was fed to a pyrolysis unit prior to entering the blast furnace. In addition to a blast furnace, this facility also had an oxidizing reverberatory furnace for processing higher purity scrap. The facility had separate baghouses for the blast furnace, the converters, and the reverberatory furnace (U.S. EPA, 1994c).

The Southwire facility has both a blast furnace and a reverberatory furnace. In 1992, approximately 50 percent of incoming scrap was processed in each furnace (U.S. EPA, 1994g). Unlike the two tested facilities and the Gaston facility, the Southwire facility stopped processing of plastic coated scrap in the 1970s. In addition, this facility has a more complex APCD system, which may also reduce the potential formation and release of CDD/CDFs. The blast furnace process gases pass through an afterburner (1,600°F), U-tube coolers, and an evaporative spray system before entering the baghouse at a temperature of 225 to 375°F.

It should be noted that a significant amount of scrap copper is consumed by other segments of the copper industry. In 1995, brass mills and wire-rod mills consumed 886,000 metric tons of copper-base scrap; foundries and miscellaneous manufacturers consumed 71,500 metric tons (U.S. Geological Survey, 1997). As noted above, however, these facilities generally do not conduct any significant purification of the scrap. Rather, the scrap consumed is already of alloy quality and processes employed typically involve only melting, casting and extruding. Thus, the potential for formation of CDDs/CDFs is expected to be much less than the potential during secondary smelting operations.

Section 4.3. Cement Kilns

Section 4.3.1. Applicability

Kilns used in the pyroprocessing of Portland Cement clinker as defined in SIC Code 3241.

Section 4.3.2. Summary Description / Air Emission Factors

In the United States, the primary cement product is called Portland cement. Portland cement is a fine, grayish powder consisting of a mixture of four basic materials: lime, silica, alumina, and iron compounds. Cement production involves heating (pyroprocessing) the raw materials to a very

high temperature in a rotary (rotating) kiln to induce chemical reactions that produce a fused material called clinker. The cement clinker is further ground into a fine powder and mixed with gypsum to form the Portland cement. The cement kiln is a large, rotating steel cylindrical furnace lined with refractory material. The kiln is aligned on a slight angle, usually a slope of 3° - 6°. This allows for the materials to pass through the kiln by gravity. The upper end of the kiln is known as the 'cold' end and this is where the raw materials, or meal, is generally fed into the kiln. Midpoint injection is practiced at some facilities. The lower end of the kiln is known as the "hot" end. The hot end is where the combustion of primary fuels (usually coal and petroleum coke) transpires to produce a high temperature. The cement kiln is operated in a counter-current configuration. This means that the hot combustion gases are convected up through the kiln while the raw materials are passing down toward the lower end. The kiln rotates about 50 to 70 revolutions per hour, and the rotation induces mixing and the forward progress of mixed materials. As the meal moves through the cement kiln and is heated by the hot combustion gases, water is vaporized and pyroprocessing of materials occurs.

When operating, the cement kiln can be viewed as consisting of three temperature zones necessary to produce cement clinker. Zone 1 is at the upper end of the kiln where the raw meal is added. Temperatures in this zone typically range from ambient up to 600°C. In this area of the kiln, moisture is evaporated from the raw meal. The second thermal zone is known as the calcining zone. Calcining occurs when the hot combustion gases from the combustion of primary fuels dissociates calcium carbonate from the limestone to form calcium oxide. In this region of the kiln, temperatures are in a range of 600°C to 900°C. The third region of the kiln is known as the burning or sintering zone. The burning zone is the hottest region of the kiln. Here temperatures in excess of 1,500°C induce the calcium oxide to react with silicates, iron and aluminum in the raw materials to form cement clinker. The formation of clinker actually occurs near the lower end of the kiln (close to the combustion of primary fuel) where temperatures are the hottest. The chemical reactions that occur here are referred to as pyroprocessing. The cement clinker that is formed and that leaves the kiln at the hot end is a gray-colored, glass-hard material comprised of dicalcium silicate, tricalcium silicate, calcium aluminate, and tetracalcium aluminoferrite. At this point, the clinker has a temperature of about 1,100°C. The hot clinker is then dumped onto a moving grate where it is cooled by passing under a series of cool air blowers. Once cooled to ambient temperature, the clinker is ground into a fine powder and mixed with gypsum to produce the Portland cement product.

Cement kilns can be either wet or dry processes. In the wet process, the raw materials are ground and mixed with water to form a slurry. The meal-water slurry is fed into the kiln through a pump. This is an older process. A greater amount of heat energy is needed in the wet process than in other types of kilns. These kilns consume about 5 to 7 trillion BTUs per ton of clinker product to evaporate the additional water.

In the dry process, a pre-heater is used to pre-dry the raw meal. A typical pre-heater consists of a vertical tower containing a series of cyclone-type vessels. Raw meal is added at the top of the

tower, and hot kiln exhaust flue gases from the kiln operation are used to preheat the meal prior to being loaded into the kiln. Pre-heating the meal has the advantage of lowering fuel consumption of the kiln. Therefore, dry kilns are now the most popular cement kiln type.

The EPA source emissions data base contains test reports of CDD/CDF emissions from 15 cement kilns not burning hazardous waste. The average CDD/CDF emission factors displayed in Table 4-7 are derived as an average from these test data.

Table 4-7. Average Emission Factors (ng/kg of cement clinker produced) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Cement Kilns Not Combusting Hazardous Waste as Supplemental Fuel

CDD Congener	Emission Factor (ng/kg clinker)	CDF Congener	Emission Factor (ng/kg clinker)
2,3,7,8-TCDD	0.012	2,3,7,8-TCDF	0.729
1,2,3,7,8-PeCDD	0.034	1,2,3,7,8-PeCDF	0.102
1,2,3,4,7,8-HxCDD	0.028	2,3,4,7,8-PeCDF	0.224
1,2,3,6,7,8-HxCDD	0.042	1,2,3,4,7,8-HxCDF	0.185
1,2,3,7,8,9-HxCDD	0.048	1,2,3,6,7,8-HxCDF	0.054
1,2,3,4,6,7,8-HpCDD	0.426	1,2,3,7,8,9-HxCDF	0.007
1,2,3,4,6,7,8,9-OCDD	0.692	2,3,4,6,7,8-HxCDF	0.082
		1,2,3,4,6,7,8-HpCDF	0.146
		1,2,3,4,7,8,9-HpCDF	0.005
		1,2,3,4,6,7,8,9-OCDF	0.234
3 CDDs	1.28	3 CDFs	1.77
3 Dioxin and dioxin-like compounds*	3.05		

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.4. Industrial Wood Combustion

Section 4.4.1. Applicability

Industrial wood combustion is the combustion of wood, wood scrap and saw dust for the primary purpose of disposing of this scrap material. A secondary purpose of the combustion of the wood scrap is the co-generation of energy in the form of steam, hot water, or electricity to offset energy usage at the facility. This applies to SIC Code 2400, LUMBER AND WOOD PRODUCT, and SIC Code 2500. FURNITURE AND FIXTURES, as follows:

24 - - . . . *LUMBER AND WOOD PRODUCT*

- C 2411 Logging*
- C 2421 Sawmills and planing mills, general*
- C 2426 Hardwood dimension & flooring mills*
- C 2429 Special product sawmills, (not elsewhere classified)*
- C 2431 Millwork*
- C 2434 Wood kitchen cabinets*
- C 2435 Hardwood veneer and plywood*
- C 2436 Softwood veneer and plywood*
- C 2439 Structural wood members, (not elsewhere classified)*
- C 2441 Nailed wood boxes and shook*
- C 2448 Wood pallets and skids*
- C 2449 Wood containers, (not elsewhere classified)*
- C 2451 Wood mobile homes*
- C 2452 Prefabricated wood buildings*
- C 2491 Wood preserving*
- C 2493 Reconstituted wood products*
- C 2499 Wood products, (not elsewhere classified)*

25 - - . . . *FURNITURE AND FIXTURES*

- C 2511 Wood household furniture*
- C 2512 Upholstered household furniture*
- C 2515 Mattresses and bedsprings*
- C 2517 Wood TV and radio cabinets*
- C 2519 Household furniture, (not elsewhere classified)*
- C 2521 Wood office furniture*
- C 2522 Office furniture, except wood*
- C 2531 Public building & related furniture*
- C 2541 Wood partitions and fixtures*
- C 2599 Miscellaneous furniture and fixtures*
- C 2591 Drapery hardware & blinds & shades*
- C 2599 Furniture and fixtures, (not elsewhere classified)*

Section 4.4.2. Summary Description/ Air Emission Factors

Congener-specific measurements of CDDs/CDFs in stack emissions from industrial wood-burning furnaces were measured by the California Air Resources Board at four facilities in 1988 (CARB, 1990b; CARB, 1990e; CARB, 1990f; CARB, 1990g). In CARB (1990b), CDDs/CDFs were measured in the emissions from a quad-cell wood-fired boiler used to generate electricity. The fuel consisted of coarse wood waste and sawdust from non-industrial logging operations. The exhaust gas passed through a multicyclone before entering the stack. In CARB (1990e), CDDs/CDFs were measured in the emissions from two spreader stoker wood-fired boilers operated

in parallel by an electric utility for generating electricity. The exhaust gas stream from each boiler is passed through a dedicated electrostatic precipitator (ESP) after which the gas streams are combined and emitted to the atmosphere through a common stack. Stack tests were conducted both when the facility burned fuels allowed by existing permits and when the facility burned a mixture of permitted fuel supplemented by urban wood waste at a ratio of 70:30. In CARB (1990f), CDDs/CDFs were measured in the emissions from a twin fluidized bed combustors designed to burn wood chips for the generation of electricity. The APCD system consisted of ammonia injection for controlling nitrogen oxides, and a multiclone and electrostatic precipitator for controlling particulate matter. During testing, the facility burned wood wastes and agricultural wastes allowed by existing permits.

In CARB (1990g), CDDs/CDFs were measured in the emissions from a quad-cell wood-fired boiler. During testing, the fuel consisted of wood chips and bark. The flue gases passed through a multicyclone and an ESP before entering the stack. The mean of the emission factors derived from the four CARB studies is used in Table 4-8 as most representative of industrial wood combustion.

Table 4-8. Average Emission Factors (ng/kg of dry wood combusted) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Industrial Wood Burning Facilities

CDD Congener	Emission Factor (ng/kg wood)	CDF Congener	Emission Factor (ng/kg wood)
2,3,7,8-TCDD	0.007	2,3,7,8-TCDF	0.673
1,2,3,7,8-PeCDD	0.044	1,2,3,7,8-PeCDF	0.790
1,2,3,4,7,8-HxCDD	0.042	2,3,4,7,8-PeCDF	0.741
1,2,3,6,7,8-HxCDD	0.086	1,2,3,4,7,8-HxCDF	0.761
1,2,3,7,8,9-HxCDD	0.079	1,2,3,6,7,8-HxCDF	0.941
1,2,3,4,6,7,8-HpCDD	0.902	1,2,3,7,8,9-HxCDF	0.343
1,2,3,4,6,7,8,9-OCDD	6.026	2,3,4,6,7,8-HxCDF	0.450
		1,2,3,4,6,7,8-HpCDF	2.508
		1,2,3,4,7,8,9-HpCDF	0.260
		1,2,3,4,6,7,8,9-OCDF	1.587
3 CDDs	7.19	3 CDFs	9.05
3 Dioxin and dioxin-like compounds*		16.24	

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.5. Utilities

Section 4.5.1. Applicability

This applies to SIC Codes 4911, 4931, and 4939 Electric Services. This guidance is for electric power utility boilers burning coal and oil for the expressed purpose of producing steam to operate a steam generator, which, in turn, generates electricity.

Section 4.5.2. Description/Emissions Factors for Coal-Fired Utility Boilers

The U.S. Department of Energy sponsored a project in 1993 to assess emissions of hazardous air pollutants at coal-fired power plants. As part of this project, CDD/CDF stack emissions were measured at seven U.S. coal-fired power plants. The levels reported for individual 2,3,7,8-substituted congeners were typically not detected or very low (i.e., #0.033 ng/Nm³). In general, CDF levels were higher than CDD levels. OCDF and 2,3,7,8-TCDF were the most frequently detected congeners (i.e., at four of the seven plants). Variation in emissions between plants could not be attributed by Riggs et al. (1995) to any specific fuel or operational characteristic. EPRI also sponsored a project to gather information of consistent quality on power plant emissions. This project, the Field Chemical Emissions Measurement (FCEM) project, included testing of four coal-fired power plants for CDD/CDF emissions. Two plants burned bituminous coal and two burned subbituminous coal. DOE has published the results of the EPRI testing of eleven plants (EPRI, 1994). The average congener and congener group emission factors derived from this 11 facility data set, as reported in EPRI (1994), are presented in Table 4-9. .

Table 4-9. Average Emission Factors (ng/kg of coal combusted) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Coal-Fired Utility Boilers

CDD Congener	Emission Factor (ng/kg coal)	CDF Congener	Emission Factor (ng/kg coal)
2,3,7,8-TCDD	0.007	2,3,7,8-TCDF	0.109
1,2,3,7,8-PeCDD	0	1,2,3,7,8-PeCDF	0.008
1,2,3,4,7,8-HxCDD	0	2,3,4,7,8-PeCDF	0.075
1,2,3,6,7,8-HxCDD	0.005	1,2,3,4,7,8-HxCDF	0.110
1,2,3,7,8,9-HxCDD	0.005	1,2,3,6,7,8-HxCDF	0.016
1,2,3,4,6,7,8-HpCDD	0.216	1,2,3,7,8,9-HxCDF	0.015
1,2,3,4,6,7,8,9-OCDD	0.517	2,3,4,6,7,8-HxCDF	0.054
		1,2,3,4,6,7,8-HpCDF	0.354
		1,2,3,4,7,8,9-HpCDF	0.097
		1,2,3,4,6,7,8,9-OCDF	0.159
3 CDD	0.75	3 CDF	1.00
3 Dioxin and dioxin-like compounds*			
	1.75		

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.5.3. Description/Emissions Factors for Oil-Fired Utility Boilers

Preliminary CDD/CDF emission factors for oil-fired utility boilers developed from boiler tests conducted over the past several years are reported in U.S. EPA (1995c). In 1993, the Electric Power Research Institute (EPRI) sponsored a project to gather information of consistent quality on power plant emissions. This project, the Field Chemical Emissions Measurement (FCEM) project, included testing of two cold side ESP-equipped oil-fired power plants for CDD/CDF emissions (EPRI, 1994). Table 4-10 presents CDD/CDF congener-specific emission factors (ng/L oil combusted) for oil-fired utility boilers.

Table 4-10. Average Emission Factors (pg/L oil combusted) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Oil-Fired Utility Boilers

CDD Congener	Emission Factor (pg /L oil)	CDF Congener	Emission Factor (pg /L oil)
2,3,7,8-TCDD	0	2,3,7,8-TCDF	0
1,2,3,7,8-PeCDD	24.7	1,2,3,7,8-PeCDF	64.1
1,2,3,4,7,8-HxCDD	63.3	2,3,4,7,8-PeCDF	49.3
1,2,3,6,7,8-HxCDD	65.8	1,2,3,4,7,8-HxCDF	76.5
1,2,3,7,8,9-HxCDD	79.7	1,2,3,6,7,8-HxCDF	35.4
1,2,3,4,6,7,8-HpCDD	477	1,2,3,7,8,9-HxCDF	0
1,2,3,4,6,7,8,9-OCDD	2055	2,3,4,6,7,8-HxCDF	23.8
		1,2,3,4,6,7,8-HpCDF	164
		1,2,3,4,7,8,9-HpCDF	0
		1,2,3,4,6,7,8,9-OCDF	0
3 CDD	2,765.5	3 CDF	413.1
3 Dioxin and dioxin-like compounds*	3,178.6		

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.6. Hazardous Waste Combustion

Section 4.6.1. Applicability

This category applies to SIC Code 4953. In particular, this guidance is applicable to commercial hazardous waste combustors (RCRA Permitted Facilities), and to boilers and industrial furnaces (BIFs) burning hazardous waste. This also includes cement kilns burning hazardous waste.

as supplemental fuel (SIC Code 3241), and Utilities (SIC Codes 4911, 4931, and 4939) that burn hazardous waste as supplemental fuel in the boiler.

Section 4.6.2. Emissions Factors for Commercial Boilers and Industrial Furnaces Burning Hazardous Waste (Other than Cement Kilns)

In 1991, EPA established rules that allow the combustion of some liquid hazardous waste in industrial boilers and furnaces (Federal Register, 1991). These facilities typically burn oil or coal for the primary purpose of generating electricity. Liquid hazardous waste can only be burned as supplemental (auxiliary) fuel, and usage is limited by the rule to no more than 5 percent of the primary fuels. These facilities typically use an atomizer to inject the waste as droplets into the combustion chamber and are equipped with particulate and acid gas emission controls. In general, they are sophisticated, well controlled facilities, that achieve good combustion. Congener-specific emission concentrations for two tested boilers burning liquid hazardous waste as supplemental fuel are available (U.S. EPA, 1998). The average congener specific emission factors are presented in Table 4-11. These emission factors reflect testing at 2 of the 136 boilers/furnaces known to combust liquid hazardous waste as supplemental fuel.

Table 4-11 Average Emission Factors (ng/kg waste feed) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Boilers and Industrial Furnaces Burning Hazardous Waste (other than cement kilns)

CDD Congener	Emission Factor (ng/kg waste feed)	CDF Congener	Emission Factor (ng/kg waste feed)
2,3,7,8-TCDD	0.00	2,3,7,8-TCDF	0.81
1,2,3,7,8-PeCDD	0.04	1,2,3,7,8-PeCDF	0.38
1,2,3,4,7,8-HxCDD	0.08	2,3,4,7,8-PeCDF	0.52
1,2,3,6,7,8-HxCDD	0.18	1,2,3,4,7,8-HxCDF	0.83
1,2,3,7,8,9-HxCDD	0.20	1,2,3,6,7,8-HxCDF	0.37
1,2,3,4,6,7,8-HpCDD	1.17	1,2,3,7,8,9-HxCDF	0.02
1,2,3,4,6,7,8,9-OCDD	5.24	2,3,4,6,7,8-HxCDF	0.56
		1,2,3,4,6,7,8-HpCDF	0.93
		1,2,3,4,7,8,9-HpCDF	0.16
		1,2,3,4,6,7,8,9-OCDF	0.70
3 CDD	6.91	3 CDF	5.28
3 Dioxin and dioxin-like compounds*			
	12.2		

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 4.6.3. Cement Kilns Burning Hazardous Waste as Supplemental Fuel

The high temperatures achieved in cement kilns make cement kilns an attractive technology for combusting hazardous waste as supplemental fuel. Sustaining the relatively high combustion temperatures (1,100°C to 1,500°C) that are needed to form cement clinker requires the burning of a fuel with a high energy output. Therefore, coal or petroleum coke is typically used as the primary fuel source. Because much of the cost of operating the cement kiln at high temperatures is associated with the consumption of fossil fuels, some cement kiln operators have elected to burn hazardous liquid and solid waste as supplemental fuel. Currently about 75 percent of the primary fuel is coal. Organic hazardous waste may have a similar energy output as coal (9,000 to 12,000 Btu/lb for coal). The strategy of combusting the waste as supplemental fuel is to off-set the amount of coal/coke that is purchased and burned by the kiln. The operator may charge a disposal fee to the waste generator for the right to combust the hazardous waste at the kiln, which also offsets the cost of kiln operation. Much of the high energy and ignitable wastes are primarily comprised of such diverse substances as waste oils, spent organic solvents, sludges from the paint and coatings industry, waste paints and coatings from the auto and truck assembly plants, and sludges from the petroleum refining industry (Greer et al., 1992). The conditions inherent in the cement kiln mimic conditions of hazardous waste incineration. For example, the gas residence time in the burning zone is typically three seconds while at temperatures in excess of 1,500°C (Greer et al., 1992). In addition, trial burns have consistently shown that 99.99 to 99.9999 percent destruction and removal efficiencies for the very stable organic wastes can be achieved in cement kilns (Greer et al., 1992). Although the combustion of hazardous waste as supplemental or substitute fuel does have apparent advantages, only 16 percent of the Portland cement kilns (34 of the 212 kilns) combusted hazardous waste in 1995 (Federal Register, 1996b). Other types of supplemental fuel used by these facilities include automobile tires, used motor oil, and sawdust, and scrap wood chips. The method of introducing liquid and solid hazardous waste into the kiln is a key factor to the complete consumption of the waste during the combustion of the primary fuel. Liquid hazardous waste is either injected separately or blended with the primary fuel (coal). Solid waste is mixed and burned along with the primary fuel. The pyroprocessing of raw meal in a cement kiln produces fine particulates. This is referred to as cement kiln dust. Cement kiln dust is collected and controlled with fabric filters and/or electrostatic precipitators. Acid gases such as SO₂ can be formed during pyroprocessing of the sulfur-laden minerals, but the minerals have high alkalinity which neutralizes SO₂ gases.

The dioxin source emissions data base contains test reports of CDD/CDF emissions from 17 cement kilns burning hazardous waste. The majority of stack emissions data from cement kilns burning hazardous waste were derived during trial burns, and may overestimate the CDD/CDF emissions that most kilns achieve during normal operations. Emission factors (ng/kg clinker produced) for Portland cement kilns burning hazardous waste as supplemental fuel are displayed in Table 4-12.

Table 4-12. Average Emission Factors (ng /kg clinker produced) for Estimating Air Releases from Cement Kilns Burning Hazardous Waste as Supplemental Fuel

Congener/Congener Group	Emission Factor ¹ APCD Inlet >450°F (ng/kg clinker produced)	Emission Factor ² APCD Inlet < 450°F (ng/kg clinker produced)
2,3,7,8-TCDD	3.38	0.02
1,2,3,7,8-PeCDD	4.28	0.13
1,2,3,4,7,8-HxCDD	4.85	0.29
1,2,3,6,7,8-HxCDD	6.93	0.42
1,2,3,7,8,9-HxCDD	9.55	0.40
1,2,3,4,6,7,8-HpCDD	27.05	3.16
1,2,3,4,6,7,8,9-OCDD	18.61	1.08
3CDDs	74.65	5.5
2,3,7,8-TCDF	36.26	3.24
1,2,3,7,8-PeCDF	13.36	0.23
2,3,4,7,8-PeCDF	23.48	0.65
1,2,3,4,7,8-HxCDF	22.24	0.55
1,2,3,6,7,8-HxCDF	8.46	0.27
1,2,3,7,8,9-HxCDF	0.96	0.06
2,3,4,6,7,8-HxCDF	13.33	0.52
1,2,3,4,6,7,8-HpCDF	7.73	0.34
1,2,3,4,7,8,9-HpCDF	2.16	0.16
1,2,3,4,6,7,8,9-OCDF	2.51	0.37
3 CDFs	130.49	6.39
3 Dioxin and dioxin-like compounds*	205.14	11.89

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

1. APCD = Air Pollution Control Device inlet temperature is > 450°F

2. APCD = Air Pollution Control Device inlet temperature is < 450°F

Section 4.6.4. Hazardous Waste Incineration (HWI) Facilities

The four principal furnace designs employed for the combustion of hazardous waste in the United States are: liquid injection, rotary kiln, fixed hearth, and fluidized-bed incinerators (Dempsey and Oppelt, 1993). The majority of commercial operations are of the rotary kiln incinerator type.

On-site (noncommercial) HWI technologies are an equal mix of rotary kiln and liquid injection facilities, with a few additional fixed hearths and fluidized bed operations (U.S. EPA, 1996h). Each of these HWI technologies is discussed below:

Rotary Kiln HWI: Rotary kiln incinerators consist of a rotating kiln, coupled with a high temperature afterburner. Because these are excess air units designed to combust hazardous waste in any physical form (i.e., liquid, semi-solid, or solid), rotary kilns are the most common type of hazardous waste incinerator used by commercial “off-site” operators. The rotary kiln is a horizontal cylinder lined with refractory material. Rotation of the cylinder on a slight slope provides for gravitational transport of the hazardous waste through the kiln (Buonicore, 1992a). The tumbling action of the rotating kiln causes mixing and exposure of the waste to the heat of combustion, thereby enhancing burnout. Solid and semi-solid wastes are loaded into the top of the kiln by an auger or rotating screw. Fluid and pumpable sludges and wastes are typically introduced into the kiln through a water-cooled tube. Liquid hazardous waste is fed directly into the kiln through a burner nozzle. Auxiliary fuel (natural gas or oil) is burned in the kiln chamber at start-up to reach elevated temperatures. The typical heating value of hazardous waste (i.e., 8,000 Btu/kg) is sufficient to sustain combustion without auxiliary fuel (U.S. EPA, 1996h). The combustion gases emanating from the kiln are passed through a high temperature afterburner chamber to more completely destroy organic pollutants entrained in the flue gases. Rotary kilns can be designed to operate at temperatures as high as 2,580 °C, but more commonly operate at about 1,100 °C.

Liquid Injection HWI: Liquid injection incinerators (LIIs) are designed to burn liquid hazardous waste. These wastes must be sufficiently fluid to pass through an atomizer for injection as droplets into the combustion chamber. The LIIs consist of a refractory-lined steel cylinder mounted either in a horizontal or vertical alignment. The combustion chamber is equipped with one or more waste burners. Because of the rather large surface area of the atomized droplets of liquid hazardous waste, the droplets quickly vaporize. The moisture evaporates, leaving a highly combustible mix of waste fumes and combustion air (U.S. EPA, 1996h). Secondary air is added to the combustion chamber to complete the oxidation of the fume/air mixture.

Fixed Hearth HWI: Fixed hearths, the third principal hazardous waste incineration technology, are starved air or pyrolytic incinerators, which are two-stage combustion units. Waste is ram-fed into the primary chamber and incinerated below stoichiometric requirements (i.e., at about 50 to 80 percent of stoichiometric air requirements). The resulting smoke and pyrolytic combustion products are then passed through a secondary combustion chamber where relatively high temperatures are maintained by the combustion of auxiliary fuel. Oxygen is introduced into the secondary chamber to promote complete thermal oxidation of the organic molecules entrained in the gases.

Fluidized-bed HWI: The fourth hazardous waste incineration technology is the fluidized-bed incinerator, which is similar in design to that used in municipal solid waste incineration. (See Section 3.1.) In this configuration, a layer of sand is placed on the bottom of the combustion

chamber. The bed is preheated by underfire auxiliary fuel at startup. During combustion of auxiliary fuel at start-up, the hot gases are channeled through the sand at relatively high velocity, and the turbulent mixing of combustion gases and combustion air causes the sand to become suspended (Buonicore, 1992a). This takes on the appearance of a fluid medium, hence the incinerator is termed a 'fluidized-bed' combustor. The incinerator is operated below the melting point temperature of the bed material. Typical temperatures of the fluid medium are within the range of 650 to 940°C. A constraint on the types of waste burned is that the solid waste particles must be capable of being suspended within the furnace. When the liquid or solid waste is combusted in the fluid medium, the exothermic reaction causes heat to be released into the upper portion of the combustion chamber. The upper portion is typically much larger in volume than the lower portion, and temperatures can reach 1,000°C (Buonicore, 1992a). This high temperature is sufficient to combust volatilized pollutants emanating from the combustion bed. In 1999, EPA promulgated final standards for the stack emission limits of dioxin and dioxin-like compounds from hazardous waste combustion facilities (64 FR 52828 - 53077; *Final Standards for Hazardous Air Pollutants For Hazardous Waste Combustors*; Final Rule; September 30, 1999). Table 4-13 displays mean CDD/CDF emission factors for estimating air releases of dioxin and dioxin-like compounds from hazardous waste combustion facilities.

Table 4-13. Average Emission Factors (ng/kg waste feed) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Hazardous Waste Combustion Facilities

CDD Congener	Emission Factor (ng/kg waste feed)	CDF Congener	Emission Factor (ng/kg waste feed)
2,3,7,8-TCDD	0.14	2,3,7,8-TCDF	2.69
1,2,3,7,8-PeCDD	0.14	1,2,3,7,8-PeCDF	2.33
1,2,3,4,7,8-HxCDD	0.18	2,3,4,7,8-PeCDF	2.51
1,2,3,6,7,8-HxCDD	0.28	1,2,3,4,7,8-HxCDF	9.71
1,2,3,7,8,9-HxCDD	0.48	1,2,3,6,7,8-HxCDF	3.95
1,2,3,4,6,7,8-HpCDD	1.75	1,2,3,7,8,9-HxCDF	0.29
1,2,3,4,6,7,8,9-OCDD	3.74	2,3,4,6,7,8-HxCDF	2.70
		1,2,3,4,6,7,8-HpCDF	16.68
		1,2,3,4,7,8,9-HpCDF	1.71
		1,2,3,4,6,7,8,9-OCDF	13.46
3 CDD	6.71	3 CDF	56.03
3 Dioxin and dioxin-like compounds*	62.74		

*3 Dioxin and dioxin-like compounds = 3 CDDs + 3 CDFs

Section 5.0. REFERENCES

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